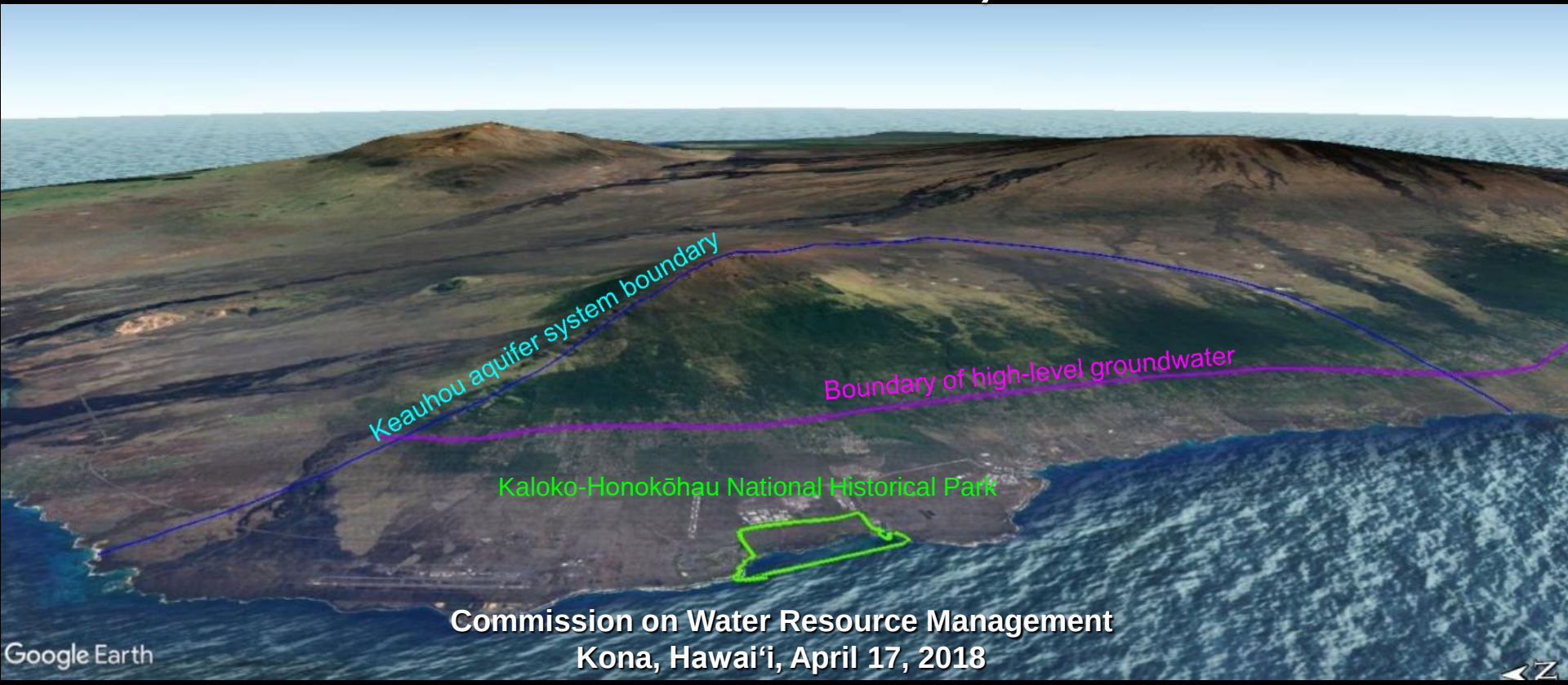
MODELING THE GROUNDWATER-FLOW SYSTEM OF THE KEAUHOU AREA, HAWAIʻI



Commission on Water Resource Management
Kona, Hawaiʻi, April 17, 2018

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Pacific Islands Water Science Center

U.S. Department of the Interior
U.S. Geological Survey

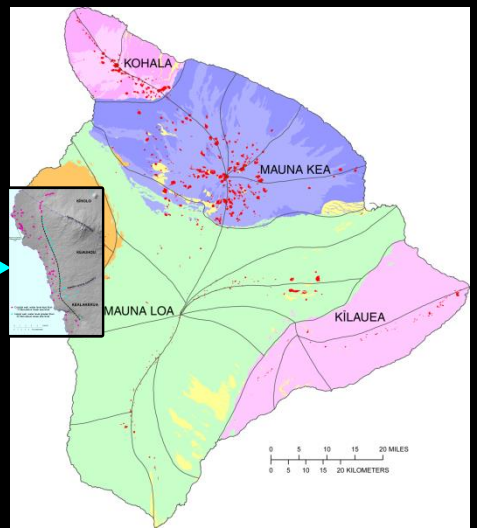
Overall Summary

- Recent information from wells in Keauhou indicates:
  - a deep zone of freshwater exists beneath the coastal freshwater-lens system
  - an unusually thick transition zone in northern Keauhou
- Geochemistry data indicate groundwater in the coastal freshwater-lens system consists of a mixture of water types, including a component of high-level groundwater
- Numerical groundwater modeling improves conceptual understanding of the groundwater-flow system and provides estimates of effects of withdrawals
- Existing information and modeling are consistent with some degree of hydrologic connection between the high-level and coastal groundwater systems

Groundwater Levels

- Well in coastal system (water table generally less than 3 ft)
- Well in inland system (water table greater than 40 ft)

Map Area →



USGS

KĪHOLO

Aquifer-system boundary

Approximate boundary separating inland and coastal systems

Kaloko-Honokōhau National Historical Park

KEAUHOU

Aquifer-system boundary

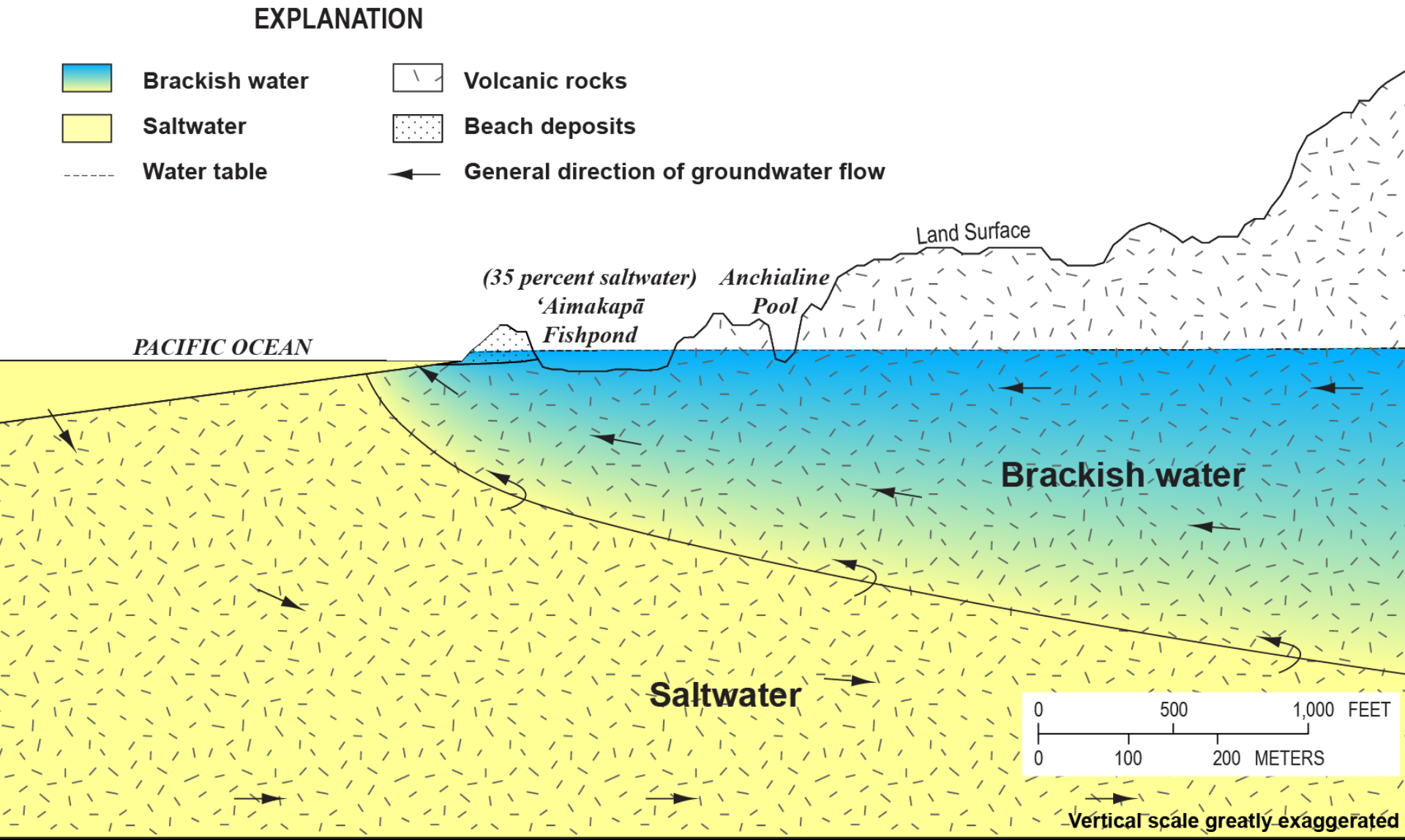
KEALAKEKUA

Coastal well, water level less than ~3 feet above mean sea level

Inland well, water level greater than 40 feet above mean sea level

0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

Coastal Groundwater System



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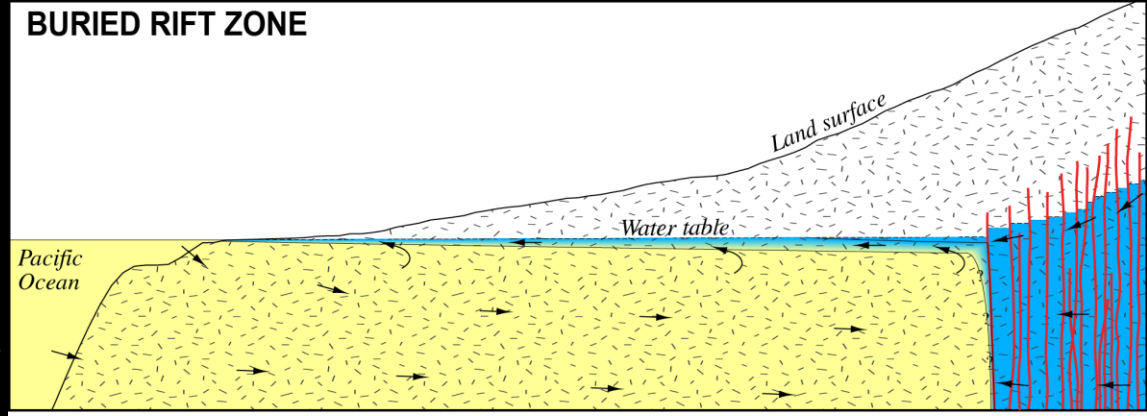
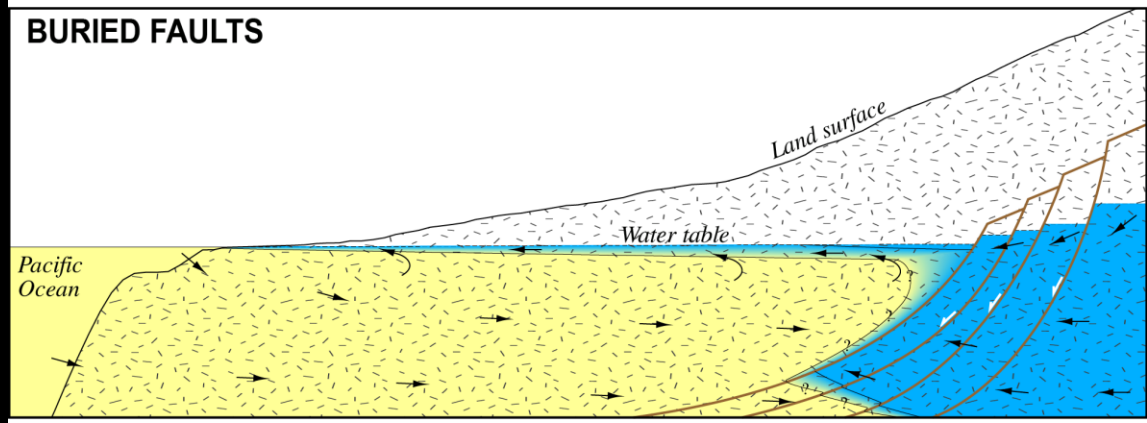
Early Conceptual Models

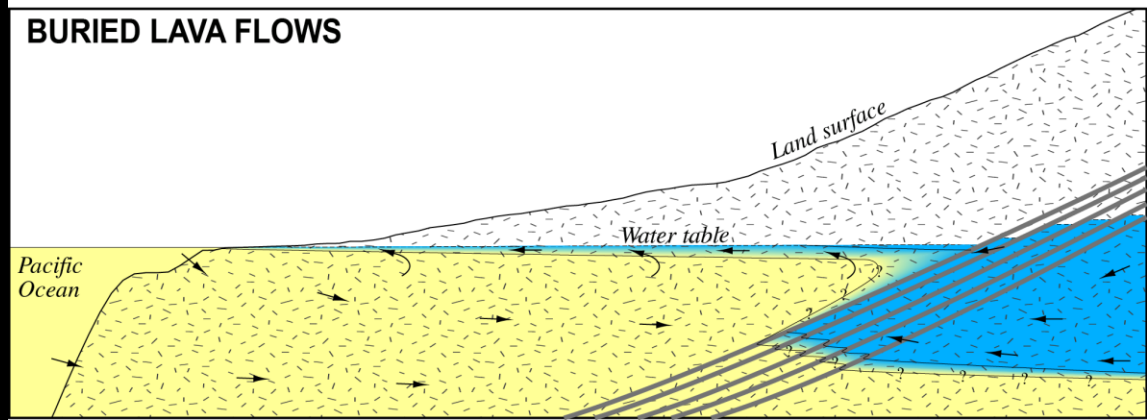
Intrusive, low-permeability dikes

Faults draped with lava flows

Low-permeability layers (ash, lava flows, weathered rock)







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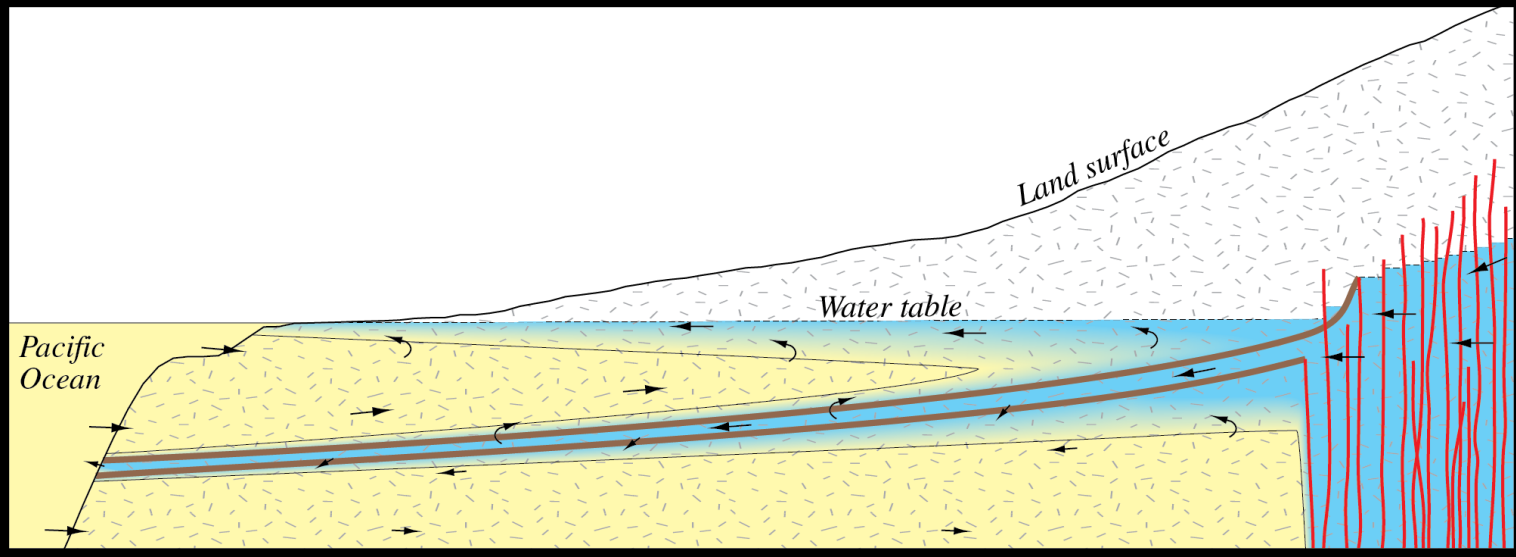
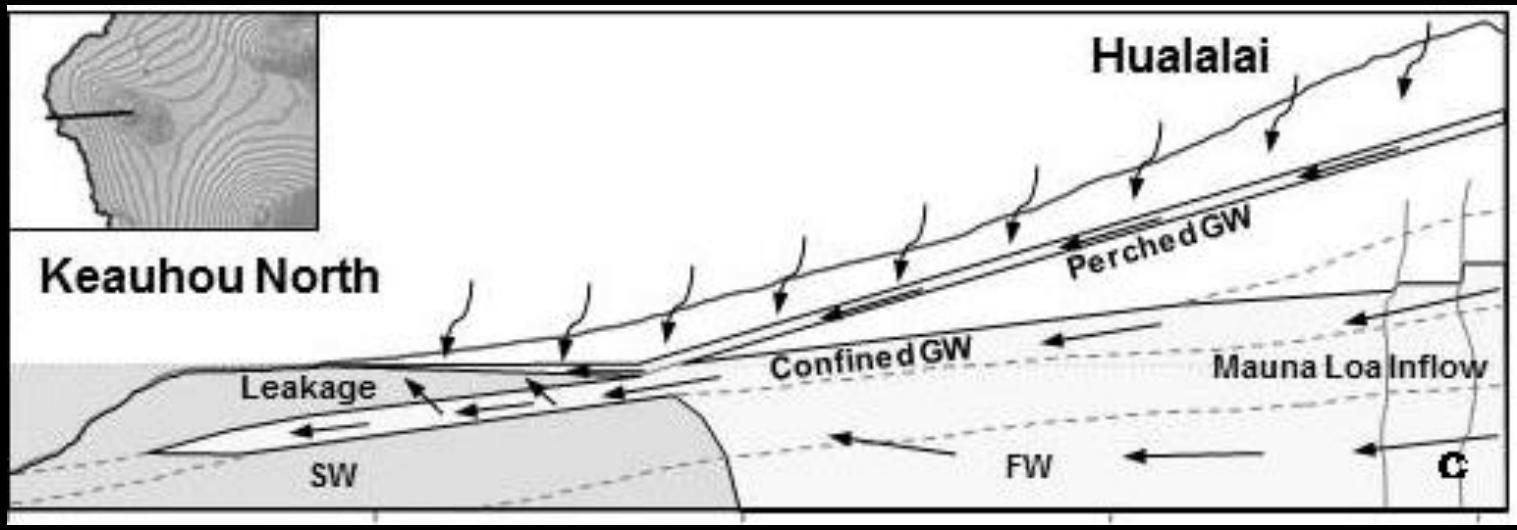
Recent Conceptual Models

Tillman and others, 2014

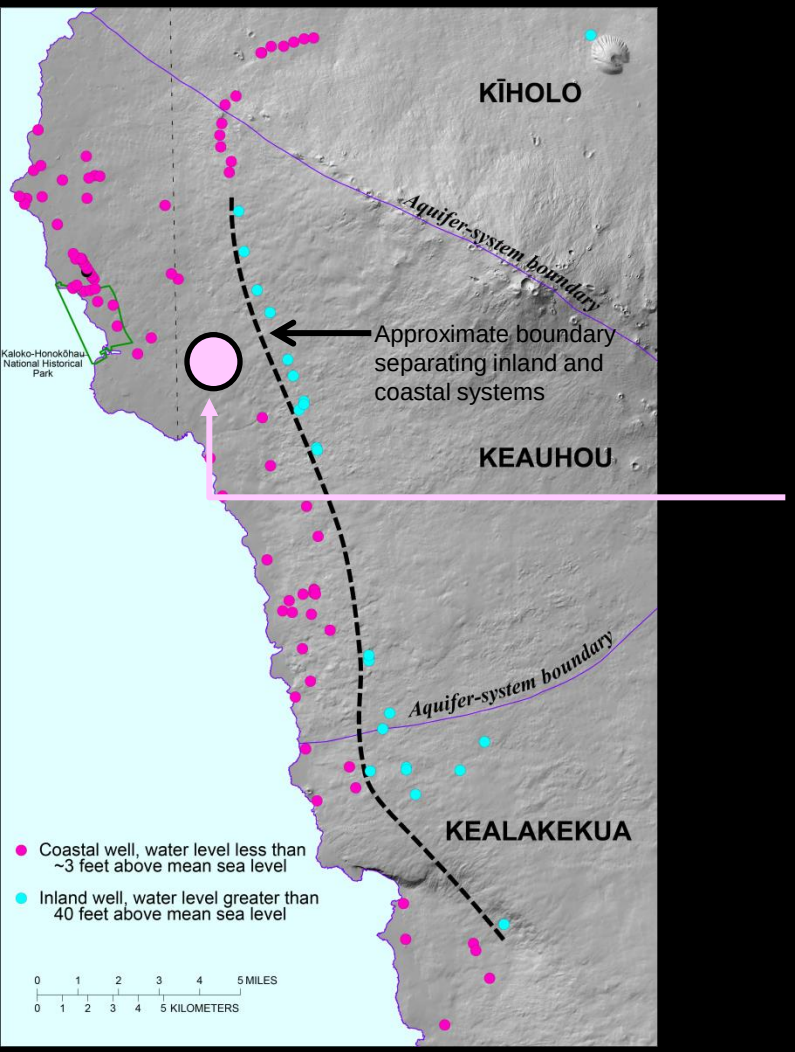


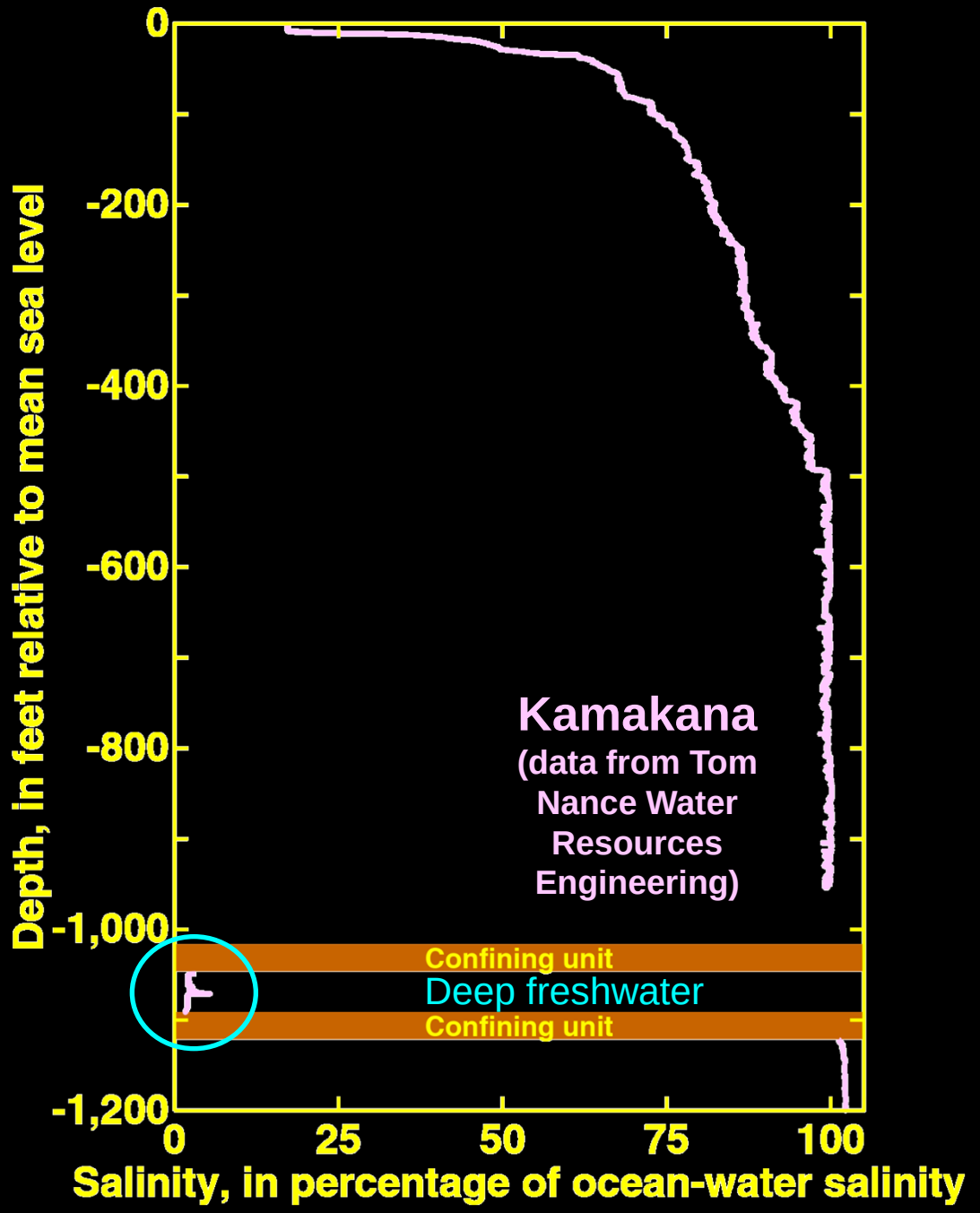
Fackrell, 2016



USGS

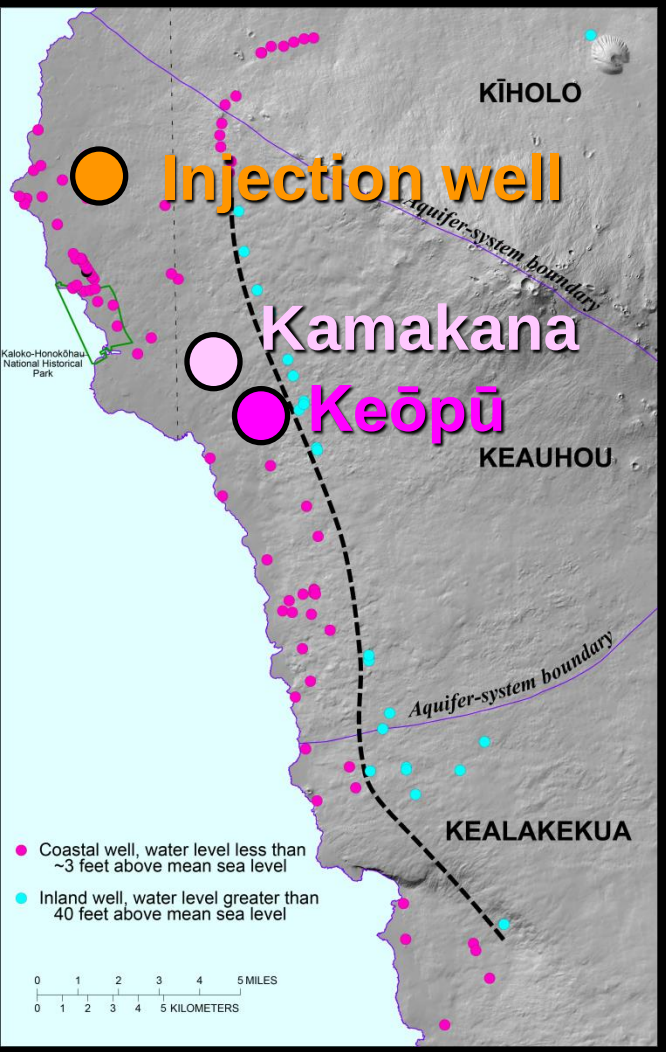
Kamakana Composite Salinity Profile

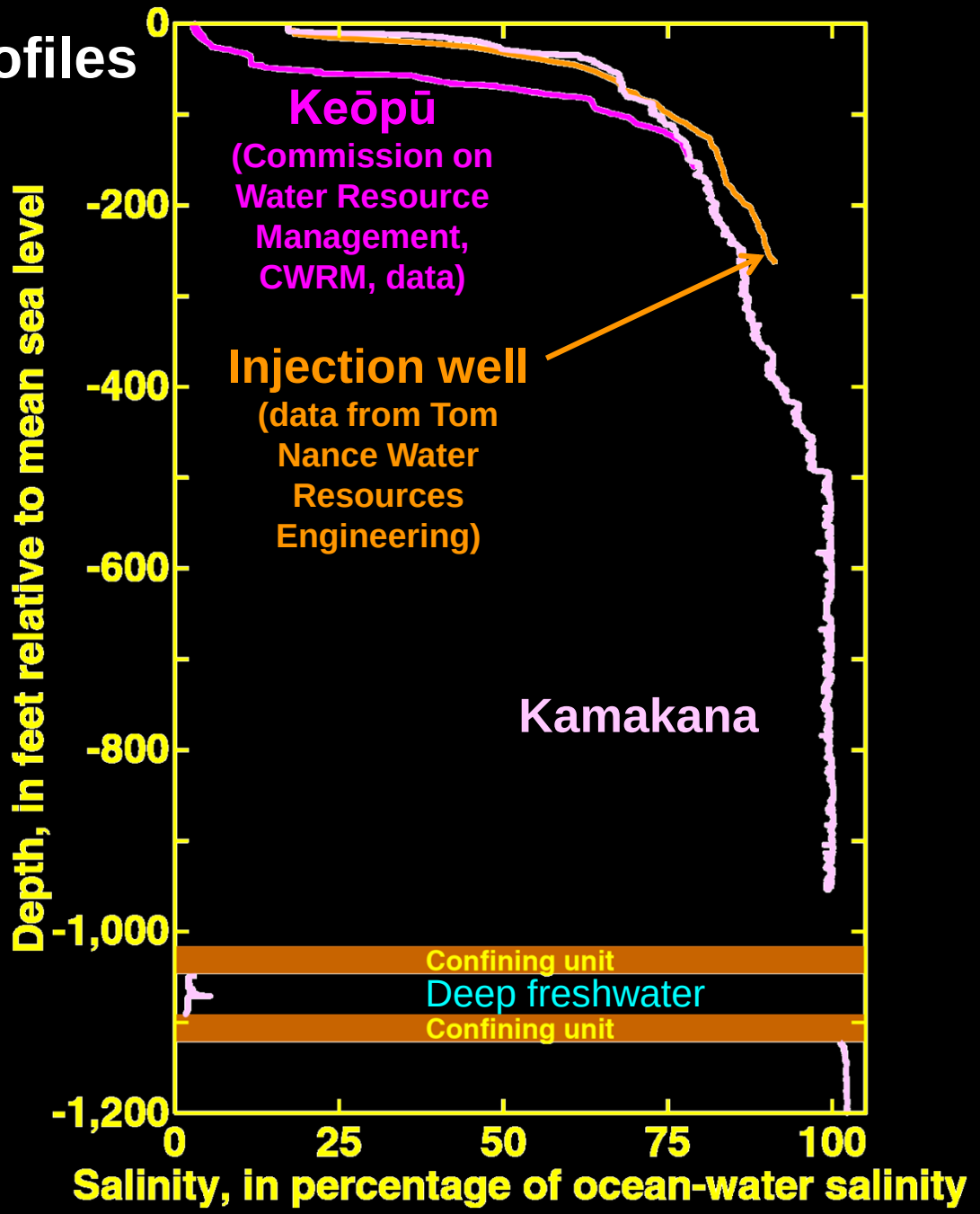




USGS

Comparison of Salinity Profiles





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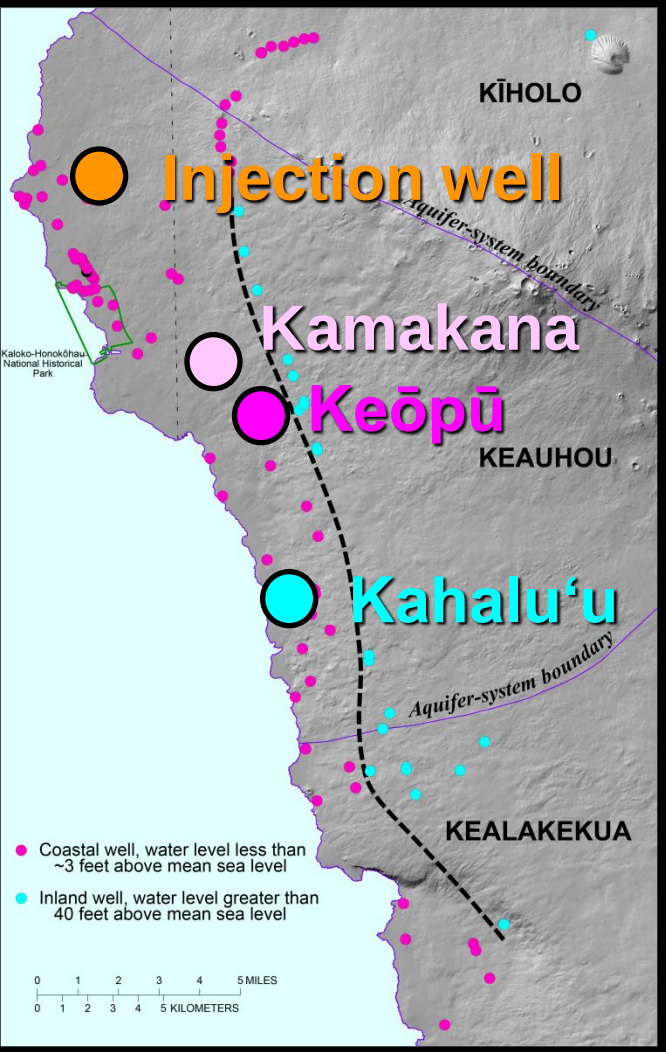
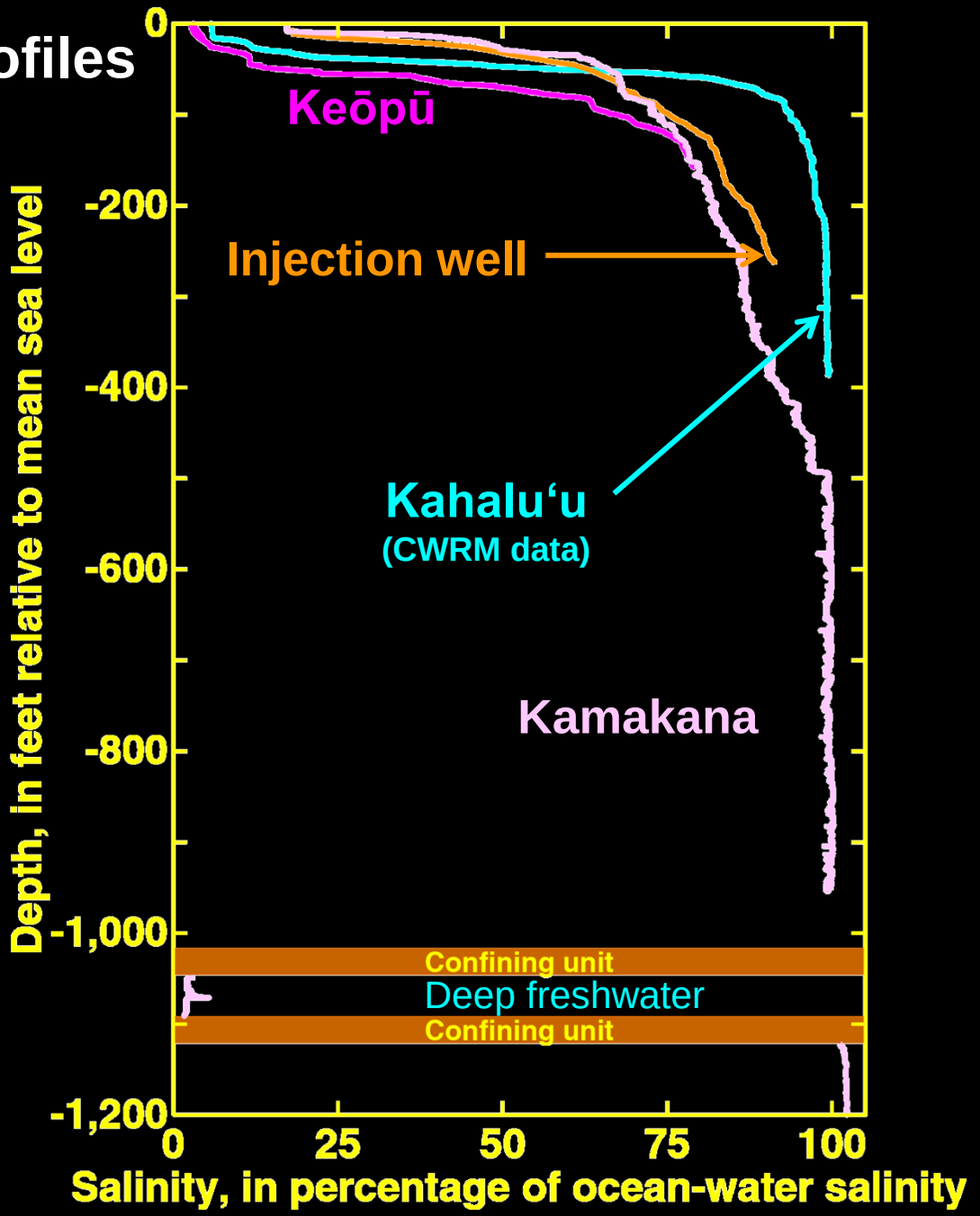
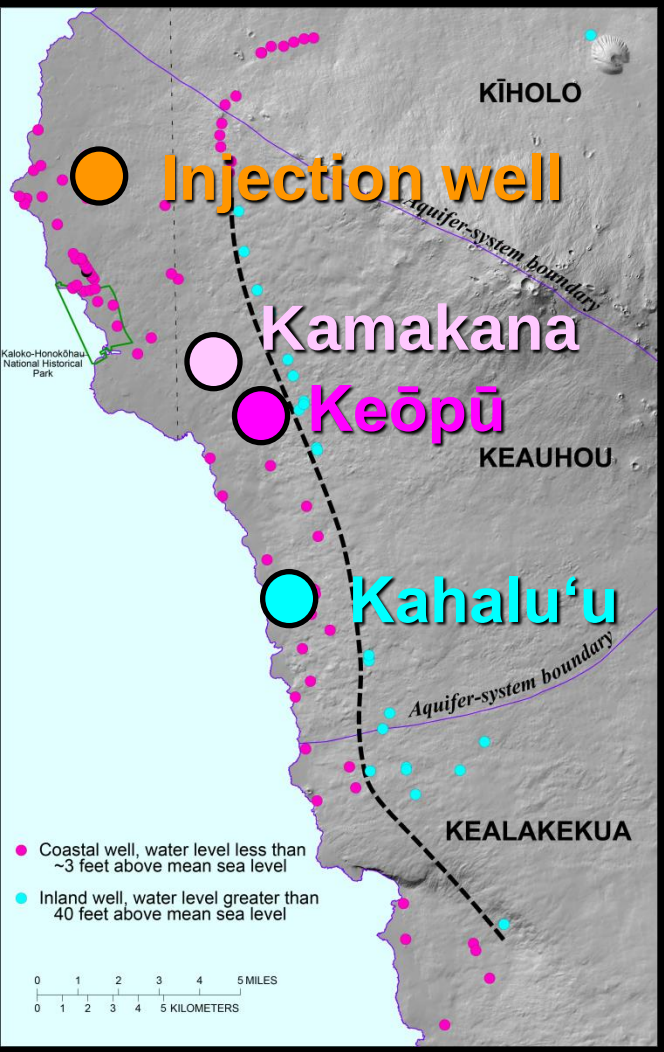
Comparison of Salinity Profiles

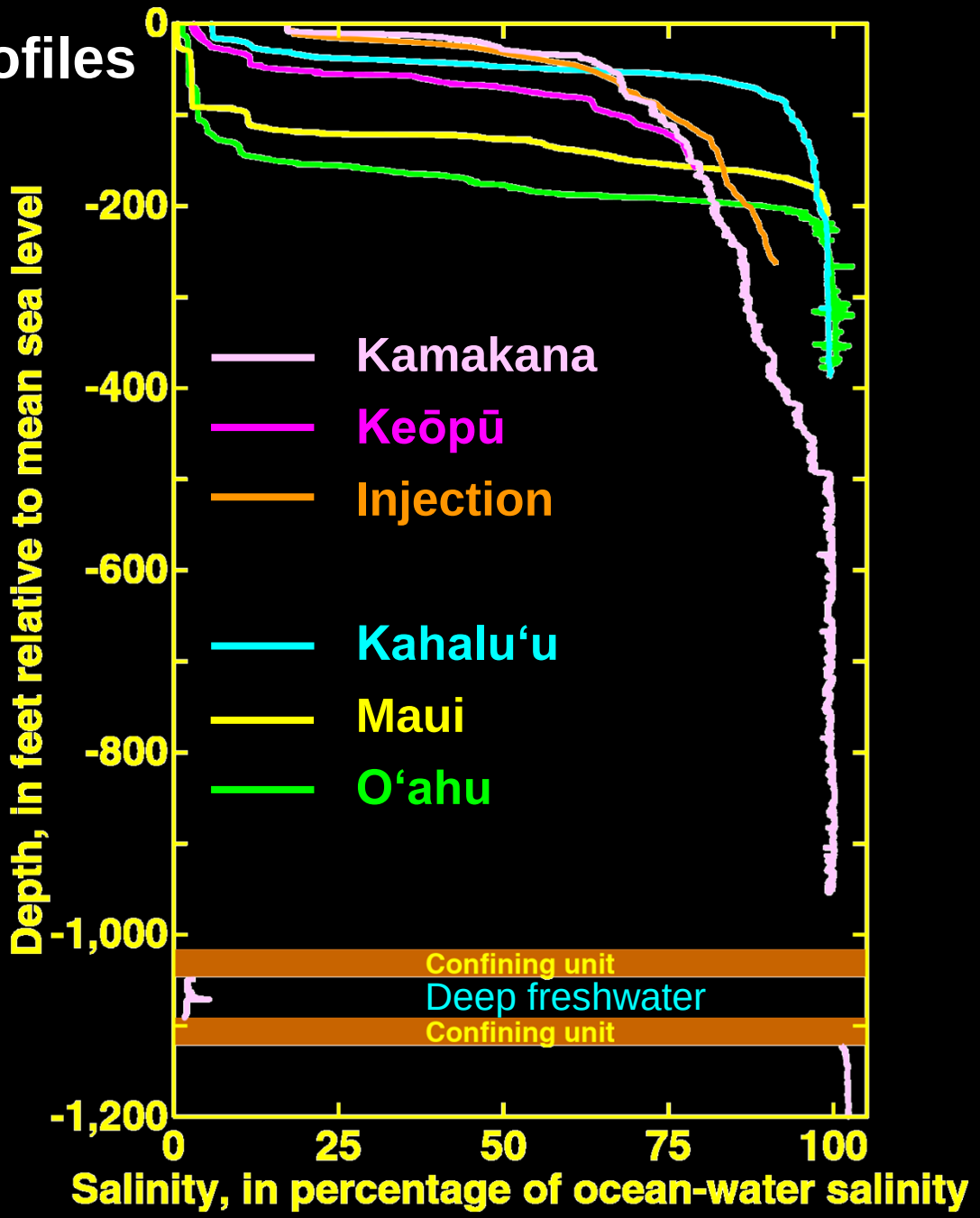




USGS

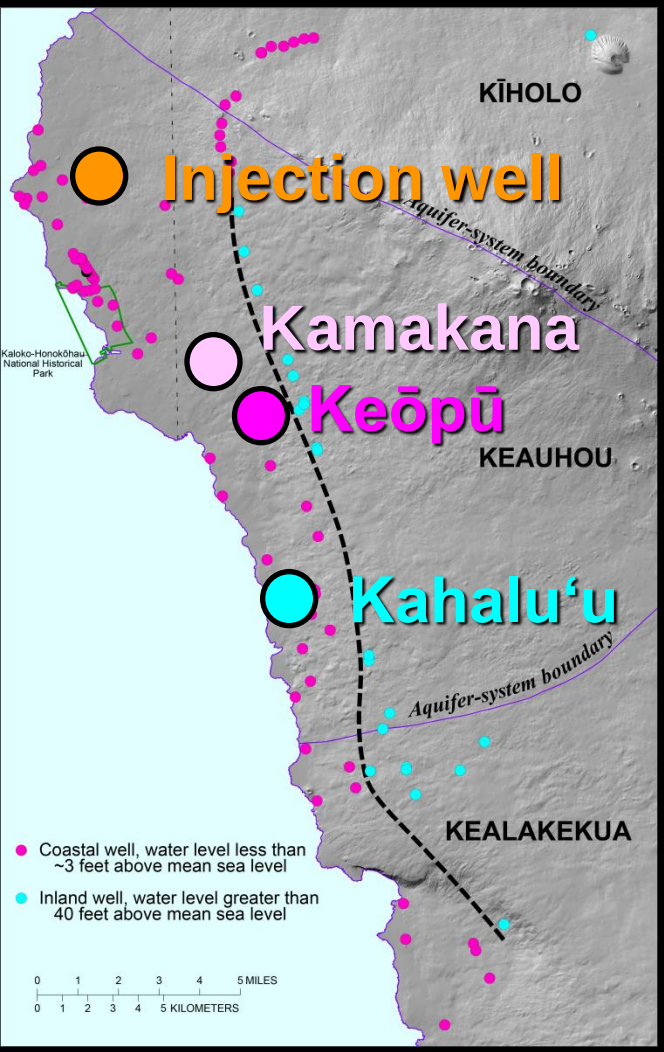
Comparison of Salinity Profiles

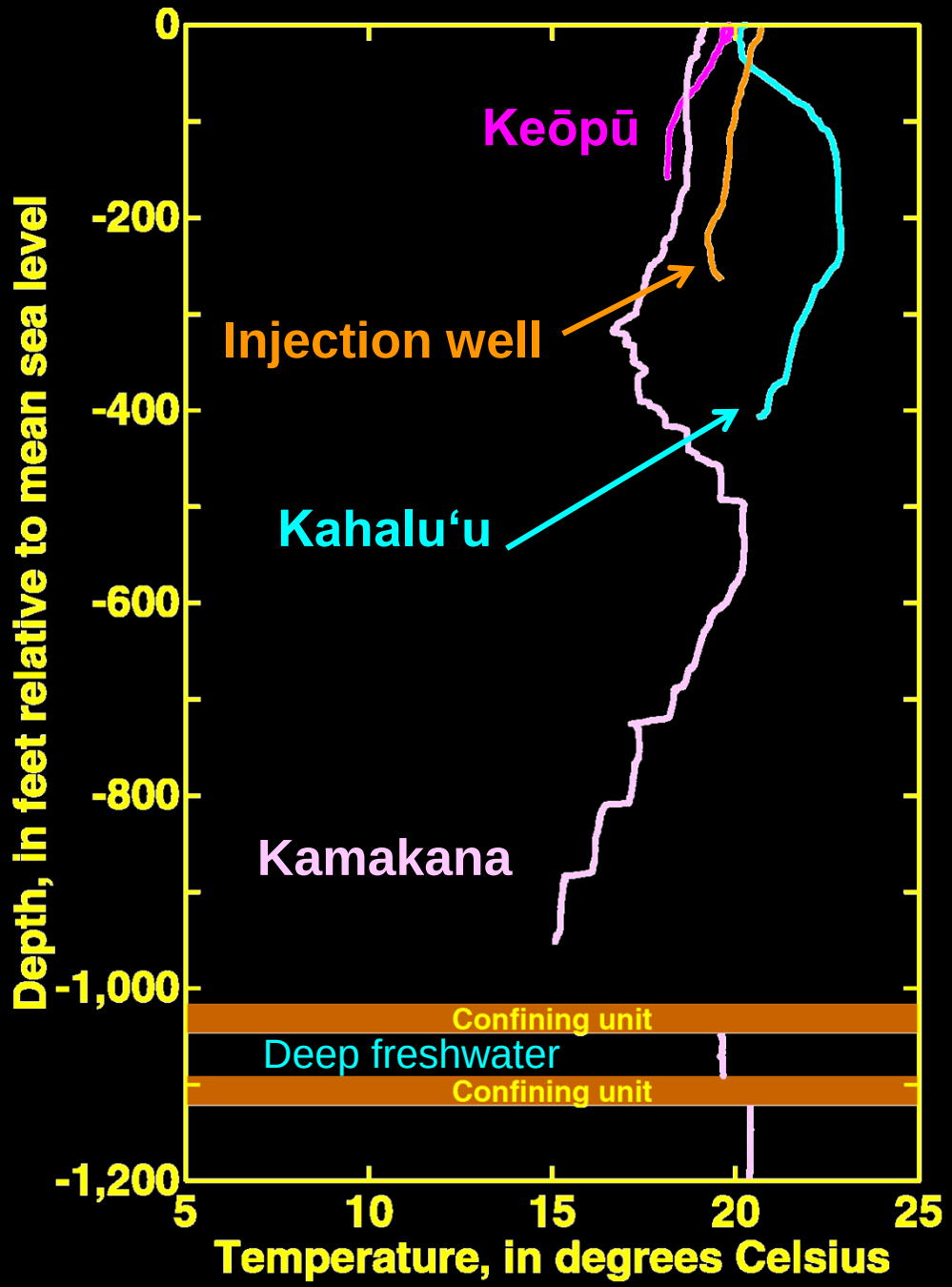




USGS

Temperature Profiles





USGS

Salinity and Temperature Profiles--Summary

- Data from deep wells indicate a zone of freshwater beneath the coastal lens
- Thick transition zone in the northern part of Keauhou aquifer system differs from other thin freshwater-lens systems
- Thick transition zone in the northern part of Keauhou aquifer system is consistent with deep freshwater discharging upward into the coastal freshwater-lens system

USGS

Groundwater Tracer Study

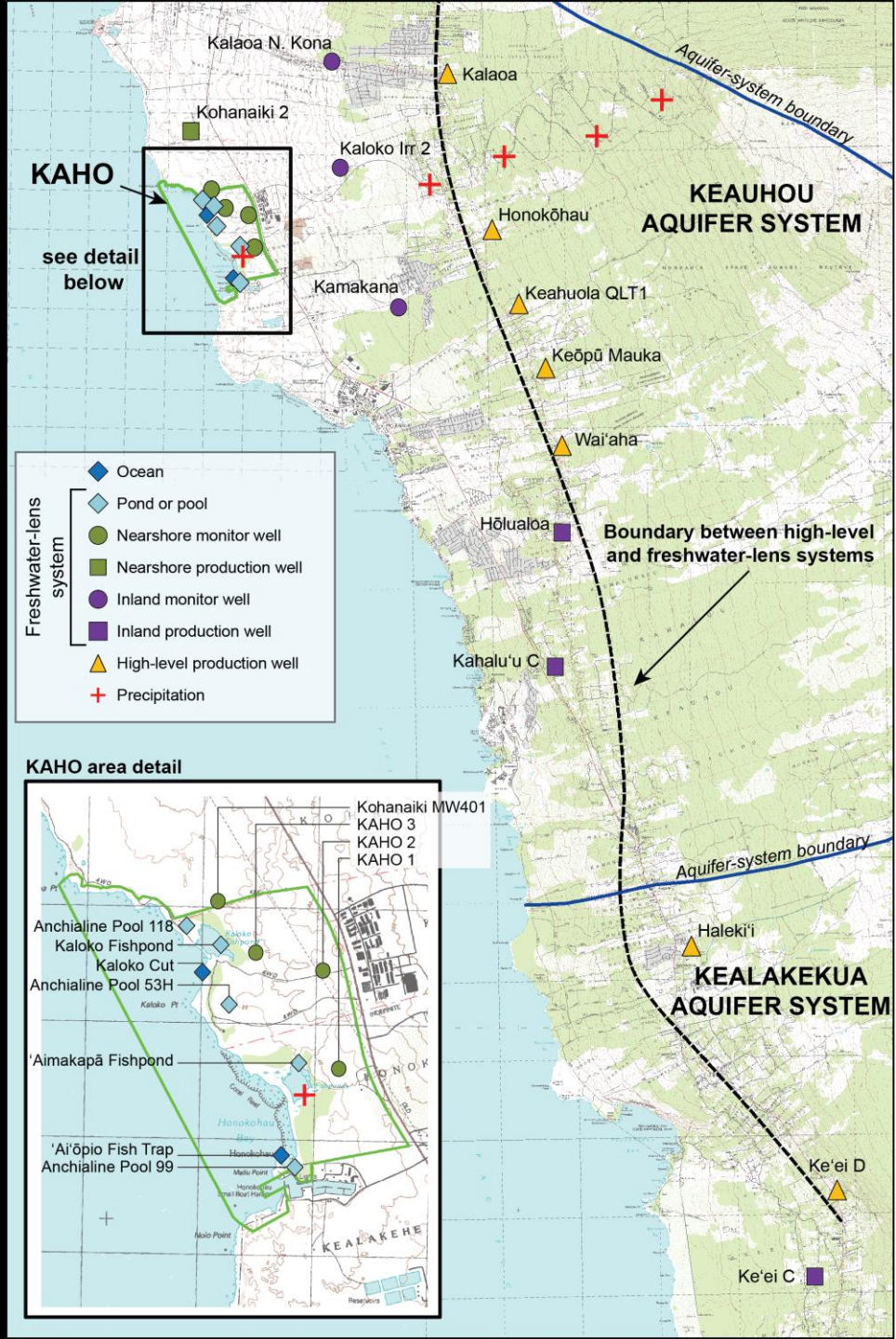
- Cooperative study
  - National Park Service
  - Commission on Water Res. Management
  - USGS
- Evaluate connection between high-level and coastal systems
- Use geochemical tracers
  - Stable isotopes (water)
  - Major ions
  - Trace elements
  - Rare earth elements
  - Strontium isotopes

USGS

Isotope Analysis

- Sample collection
  - 2 ocean sites
  - 5 pools/ponds
  - 7 monitor wells
  - 11 production wells
  - 5 precipitation collectors

- Ternary mixing analysis (assume coastal groundwater is derived from three isotopically distinct sources)
  1. Ocean water
  2. High-level groundwater
  3. Rain



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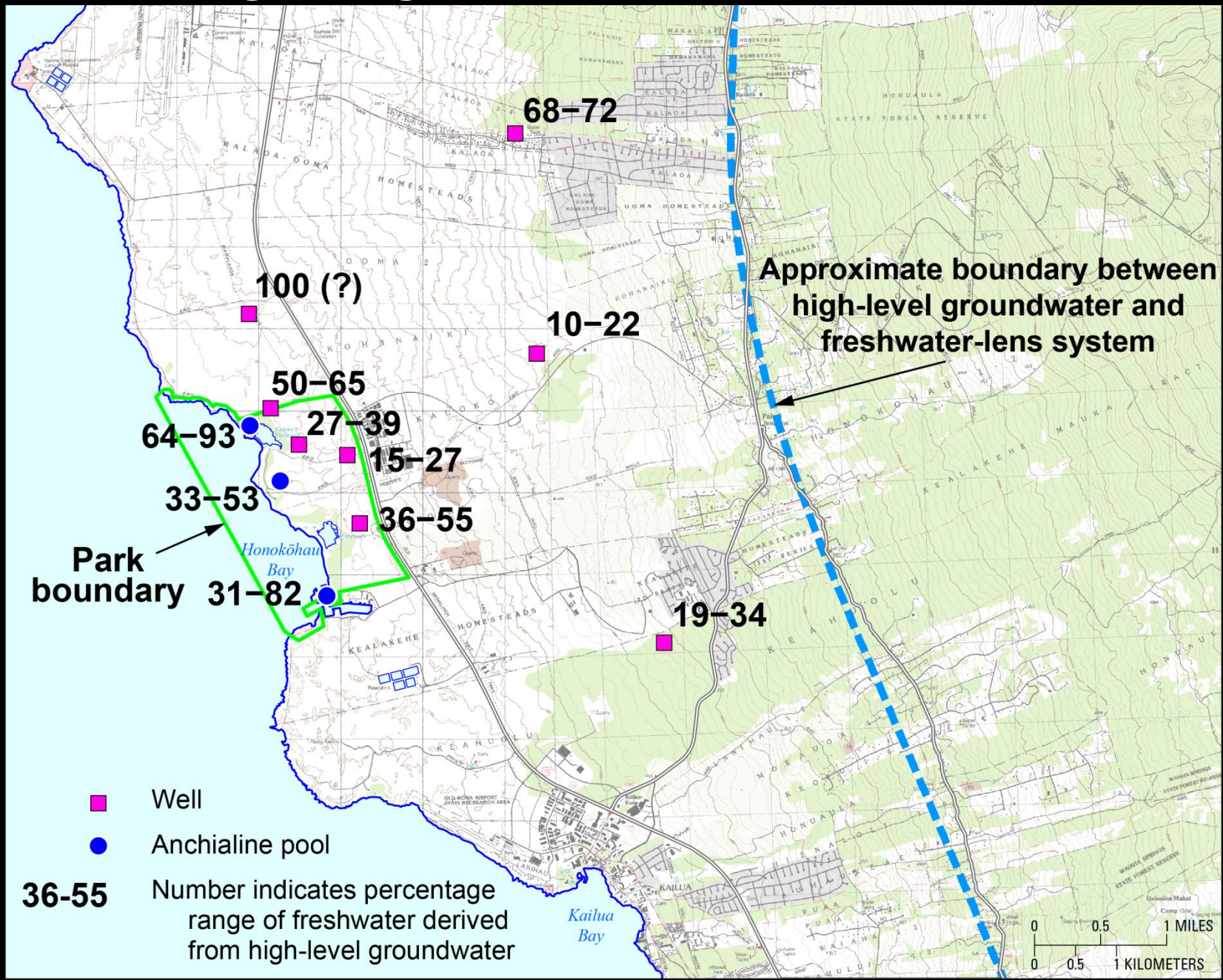
Percentage High-Level Groundwater

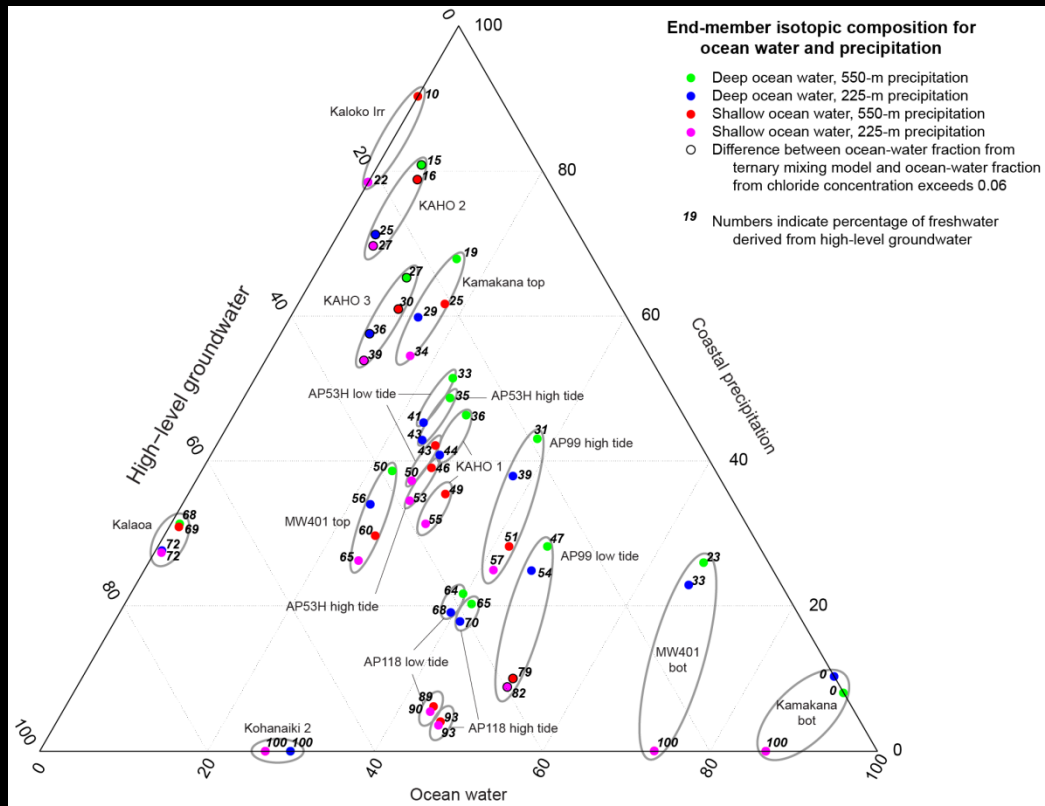


USGS

Groundwater Tracers--Summary

- Results of independent studies of water isotopes (Fackrell and Glenn, 2014; Tillman and others, 2014) are consistent with a conceptual model of coastal groundwater containing a mixture of:
  1. high-level groundwater
  2. local recharge
  3. ocean water

- Most water samples from sites in the Park indicate about 25-70 percent of freshwater component is derived from high-level groundwater



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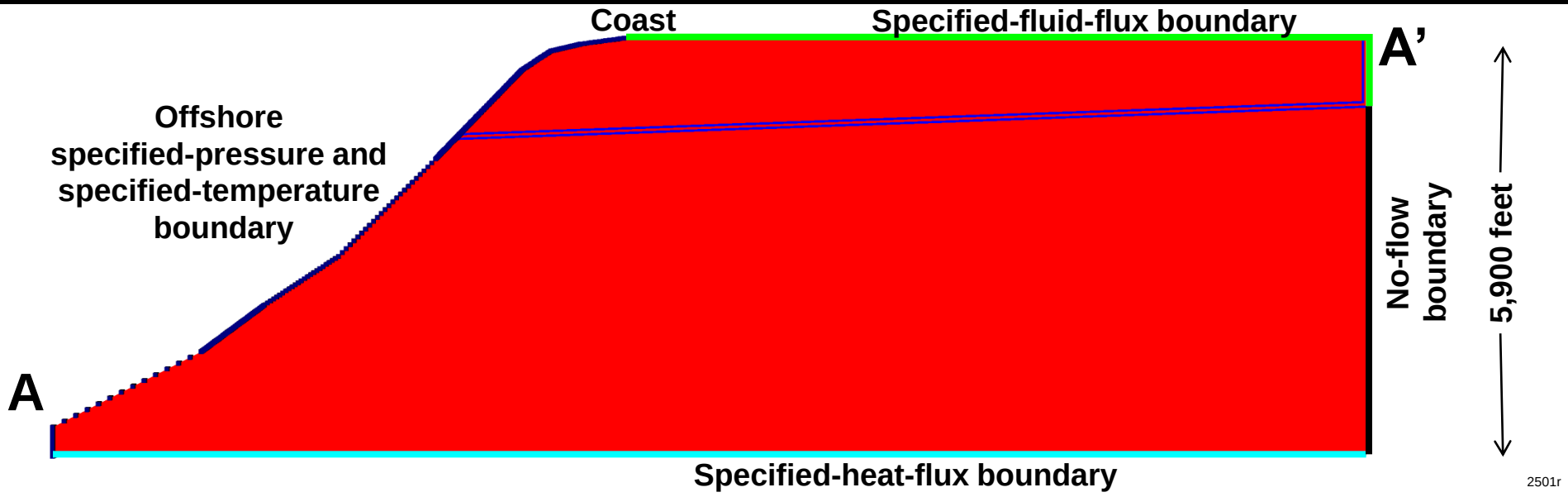
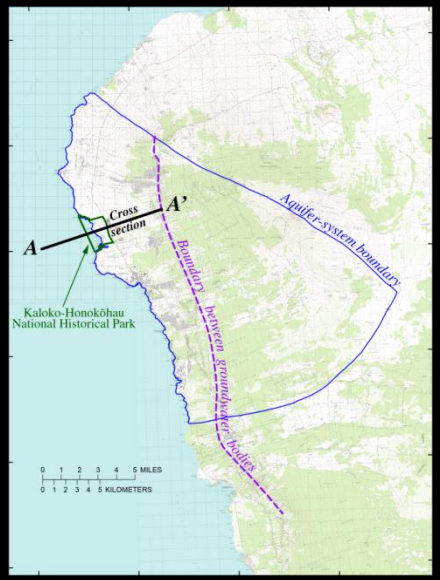
Groundwater Modeling

- Numerical groundwater models developed to:
  - Improve conceptual understanding of groundwater flow
  - Quantify effects of withdrawals on Kaloko-Honokōhau National Historical Park (KAHO) resources
- 2D and 3D models
  - 2D models used to test different conceptual models
  - 3D model simulates changes in salinity and discharge associated with withdrawals or injections at selected sites

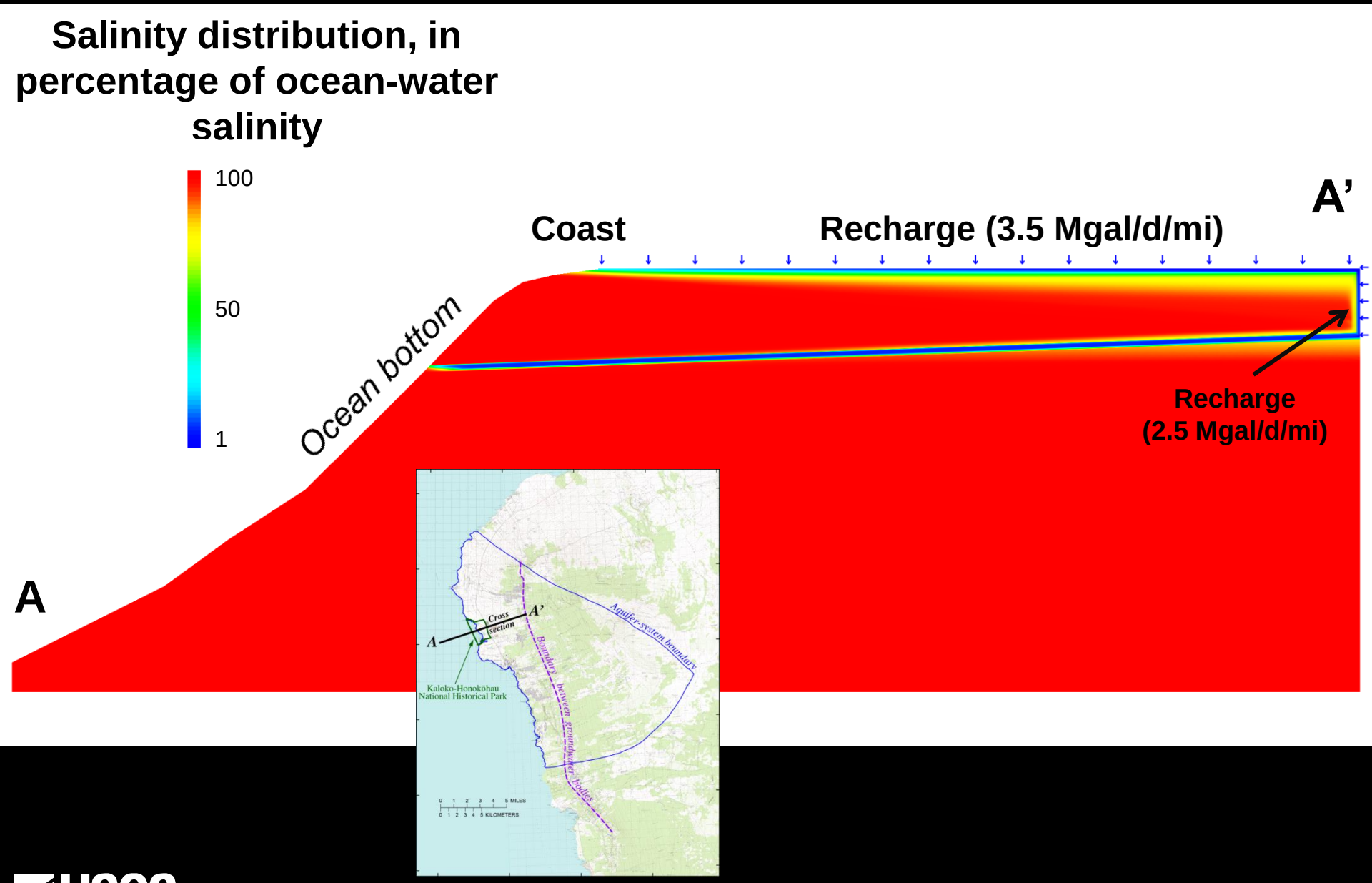
2D Cross-Section Model



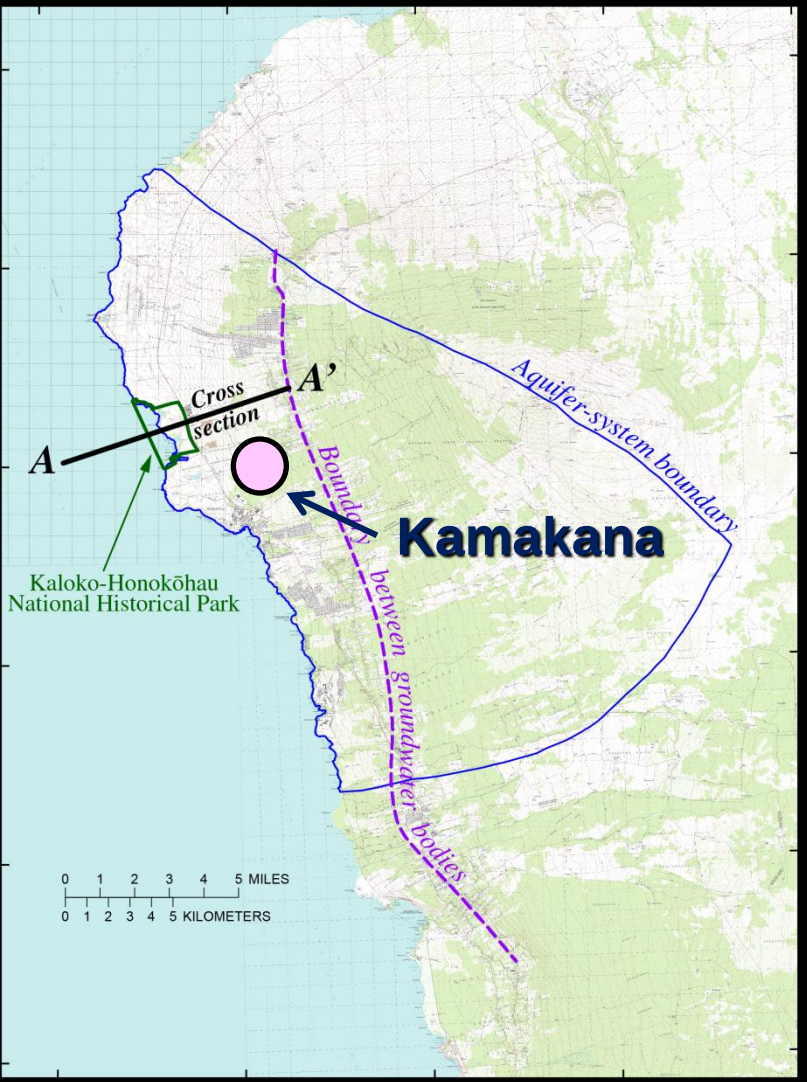


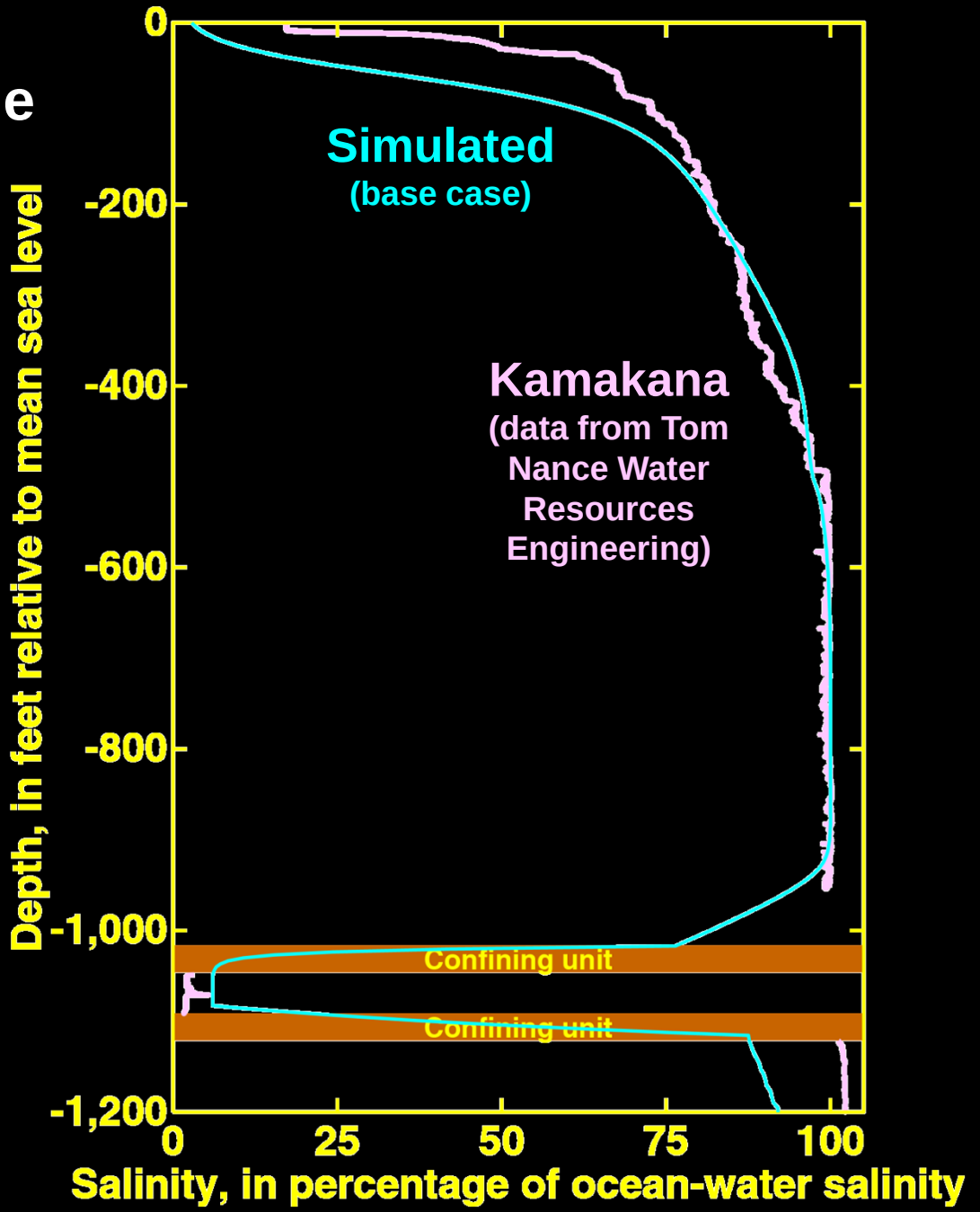
- Simulate salinity and heat
- Model generally able to represent observed salinity and temperature distributions

2D Cross-Section Model—Simulated Salinity



Simulated Salinity Profile





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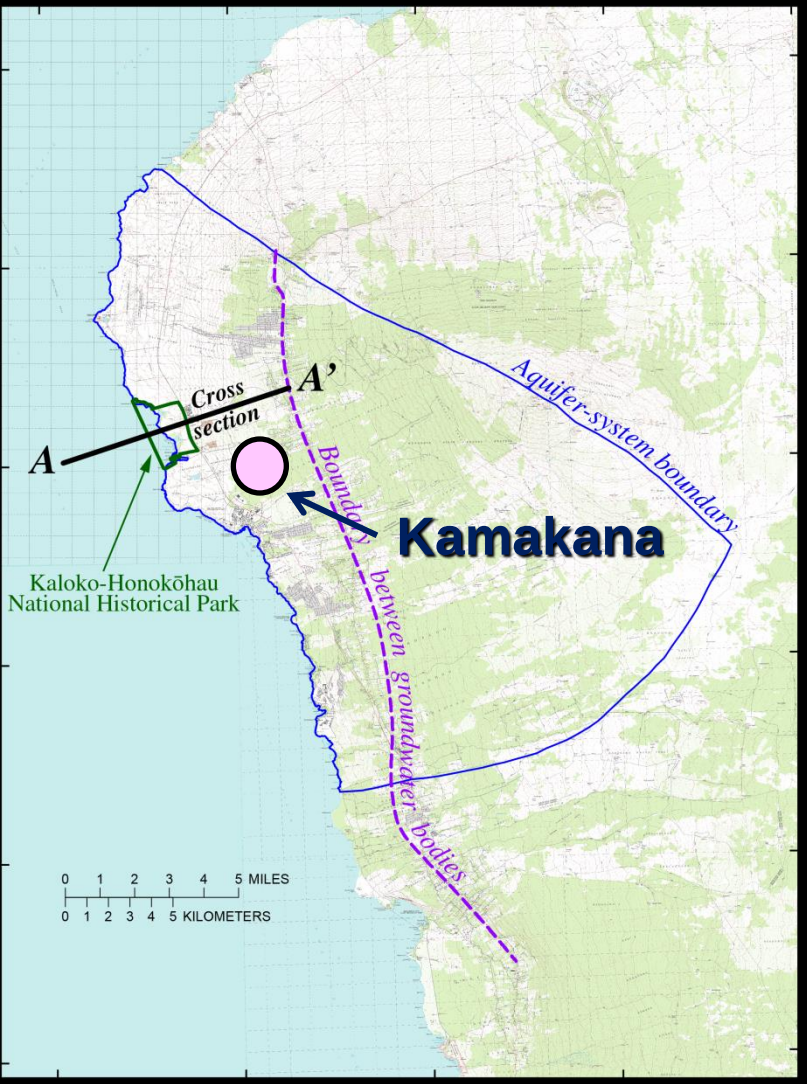
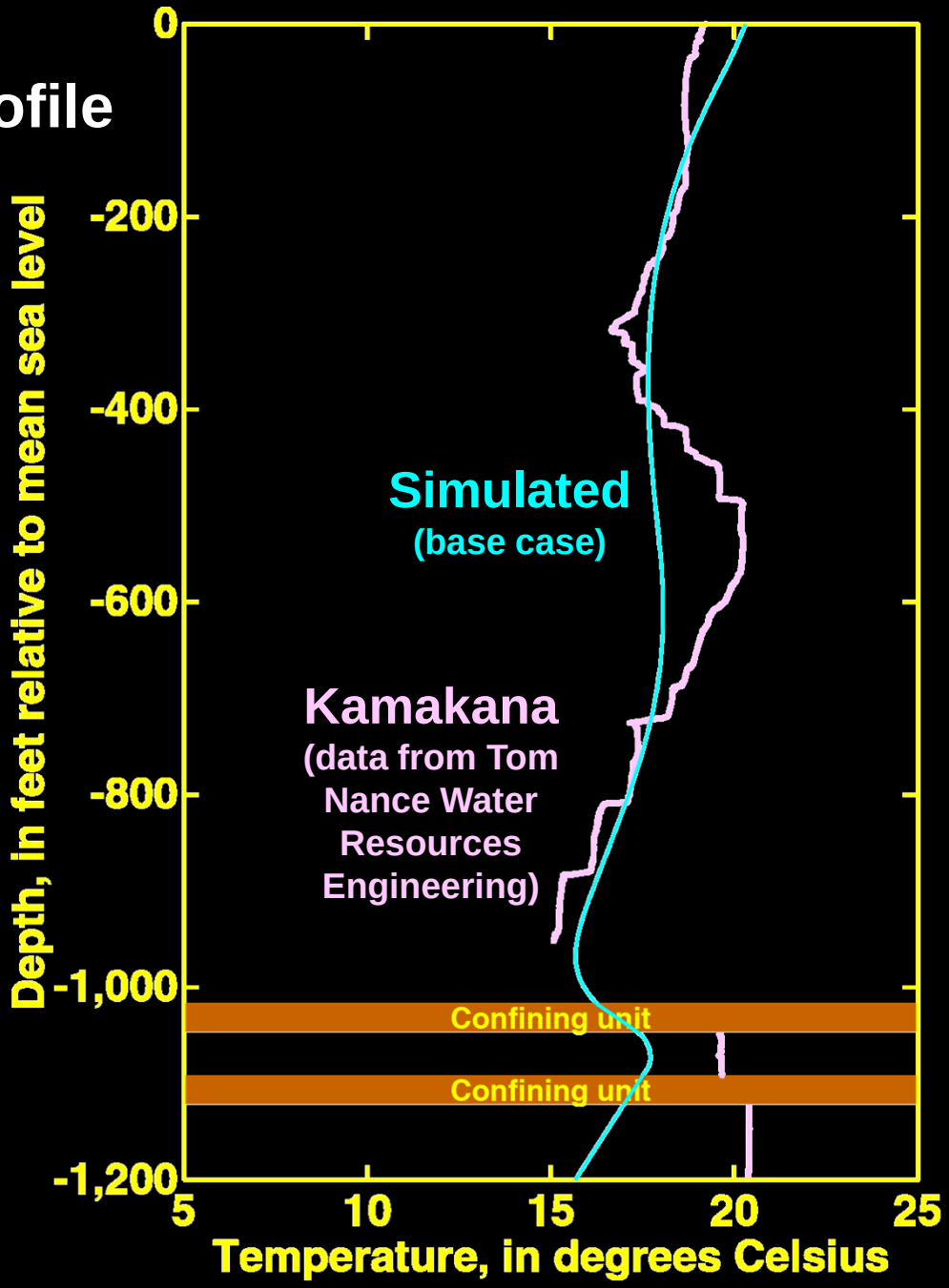
Simulated Temperature Profile

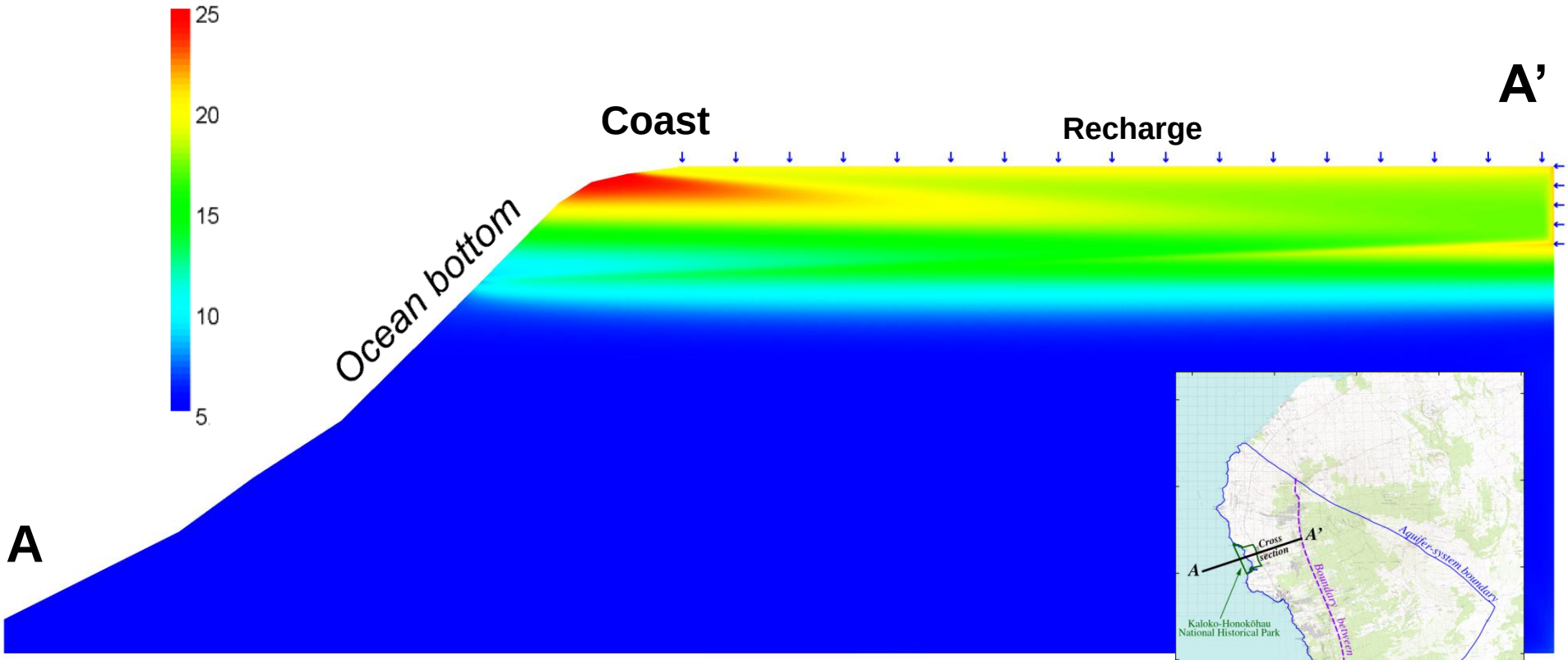




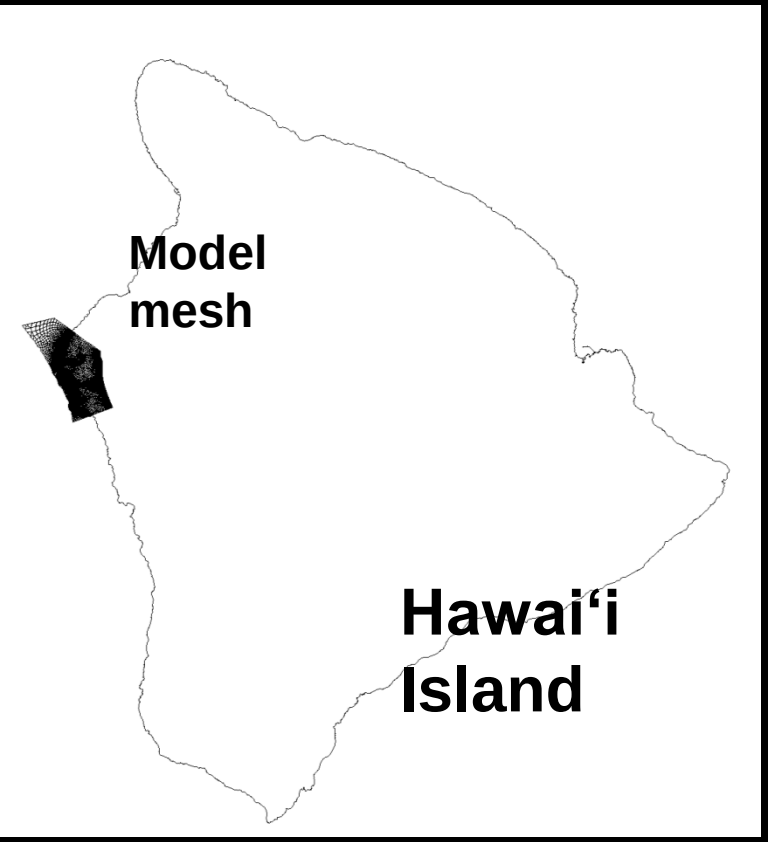
USGS

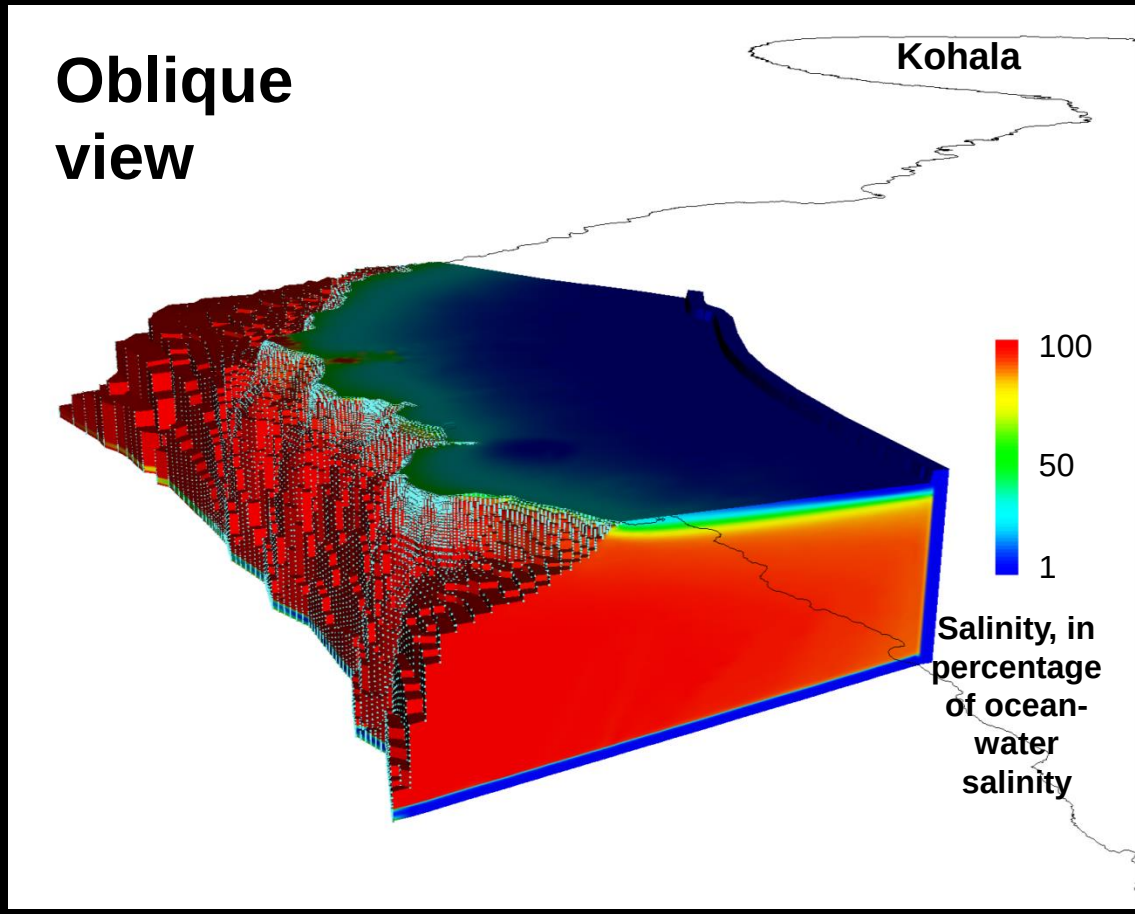
2D Cross-Section Model—Simulated Temperature

Temperature distribution, in degrees Celsius



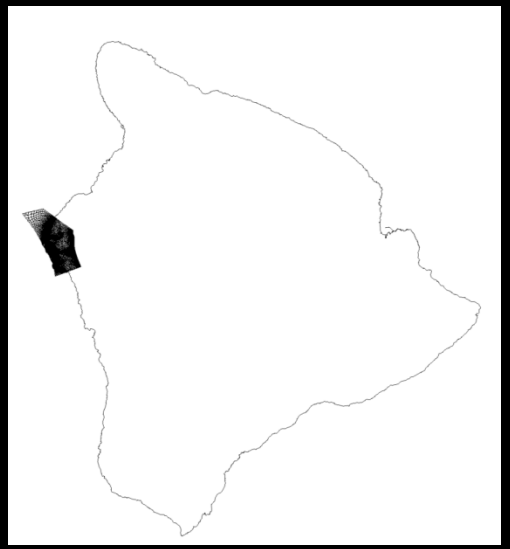
3D Model

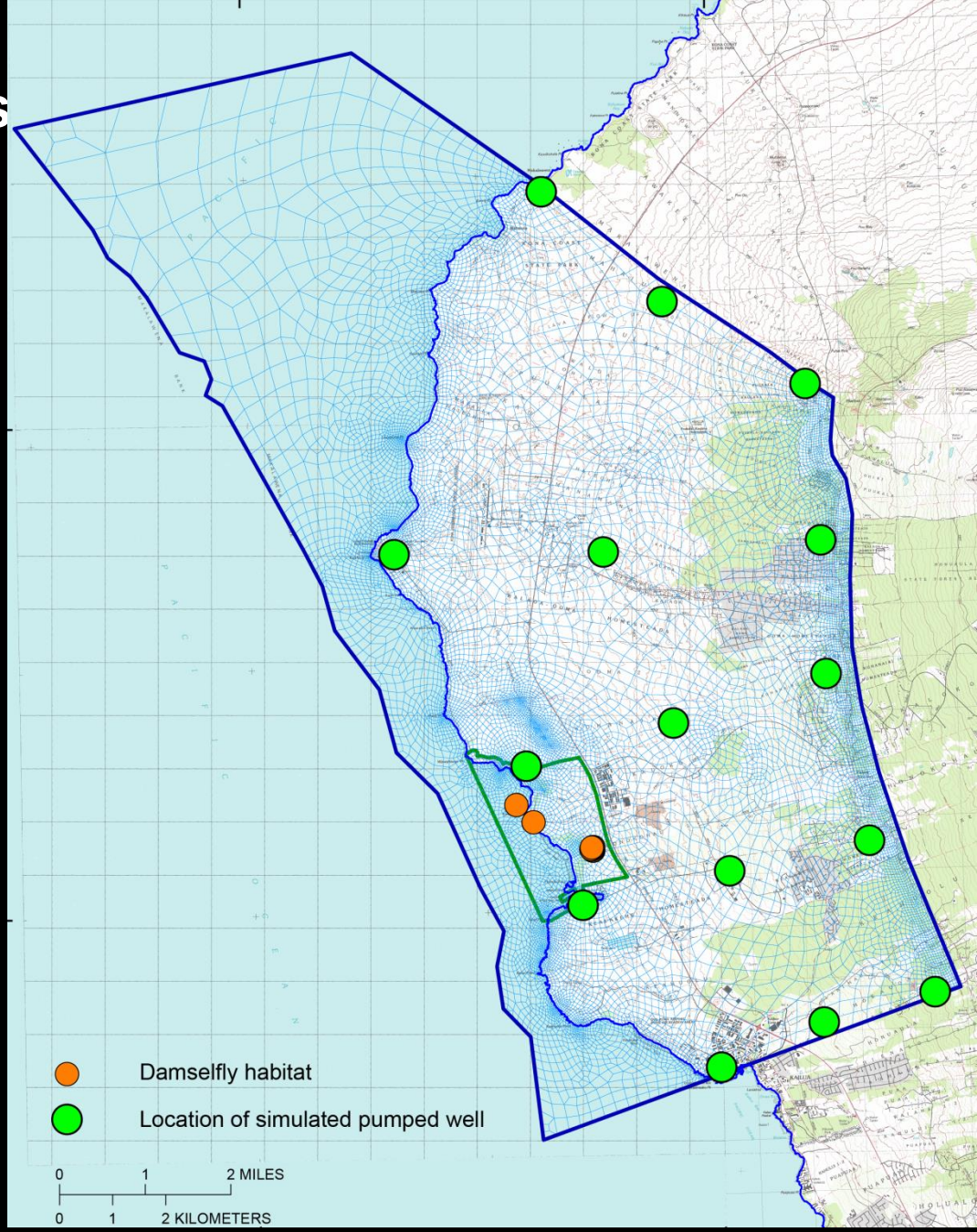




0.5 Mgal/d Withdrawal Sites

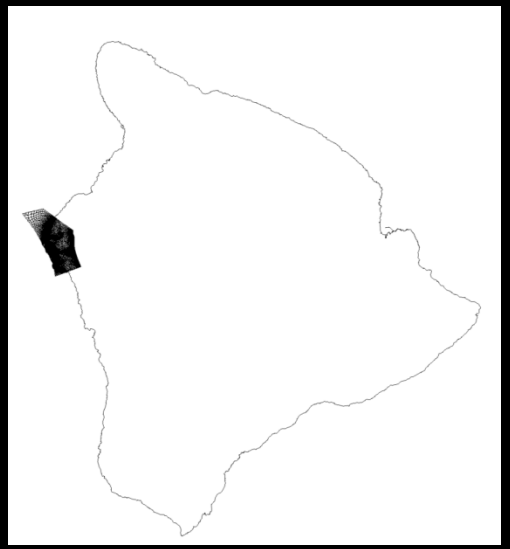
- Pump one site at a time
- Observe effects of withdrawal at each site in terms of:
  - salinity in selected pools
  - discharge through Park

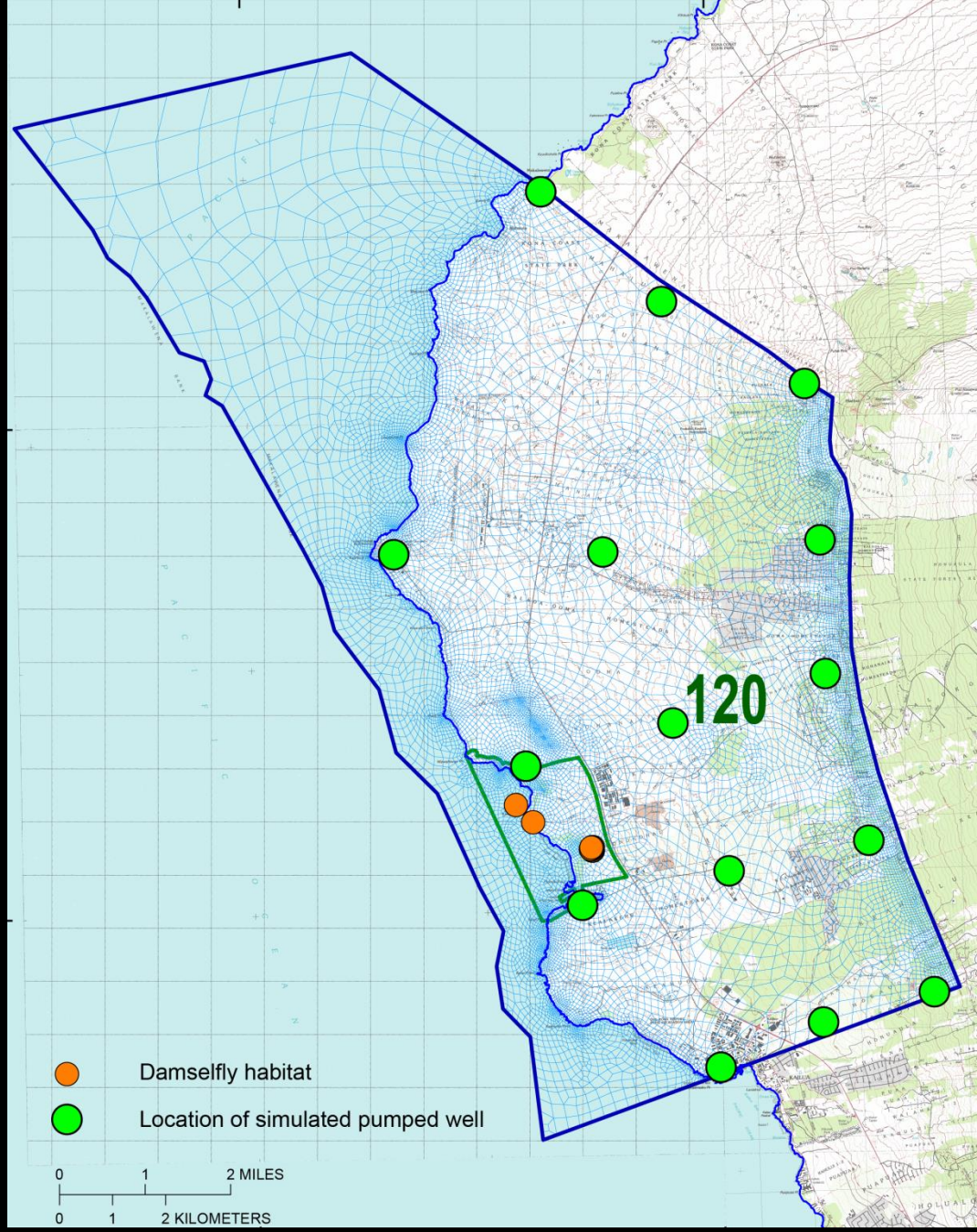




0.5 Mgal/d From Site 1

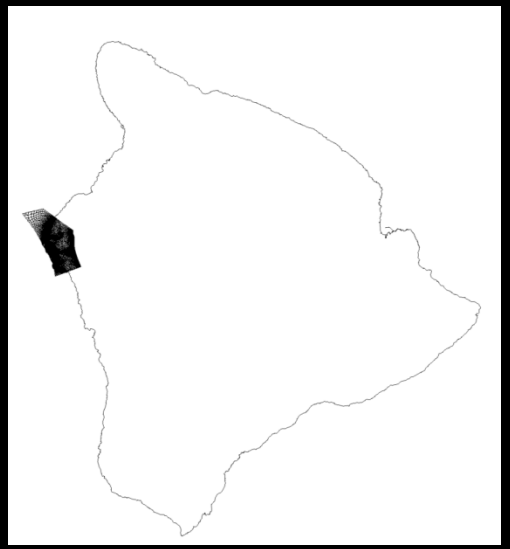
- Chloride concentration increases by 120 mg/L in selected damselfly pools

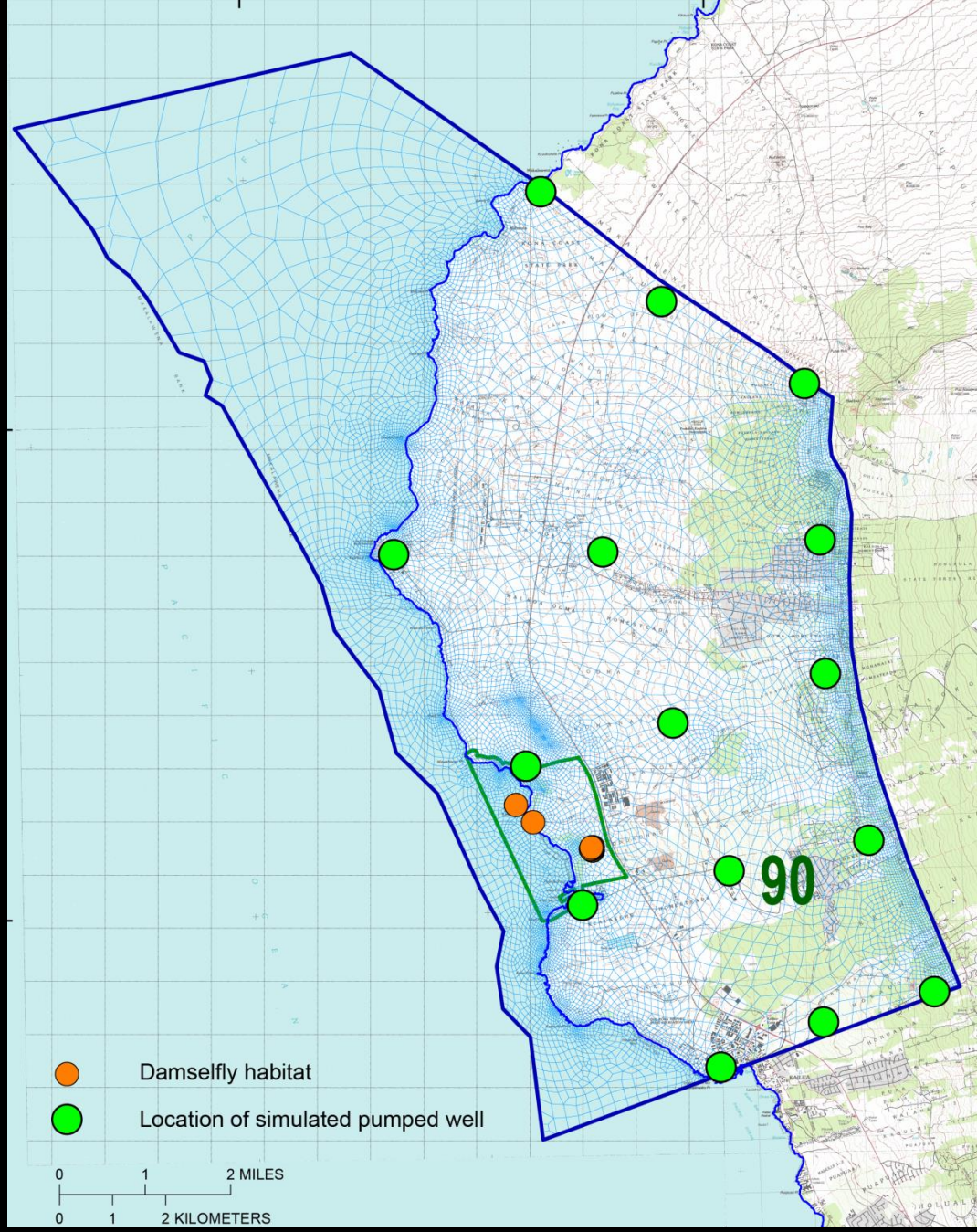




0.5 Mgal/d From Site 2

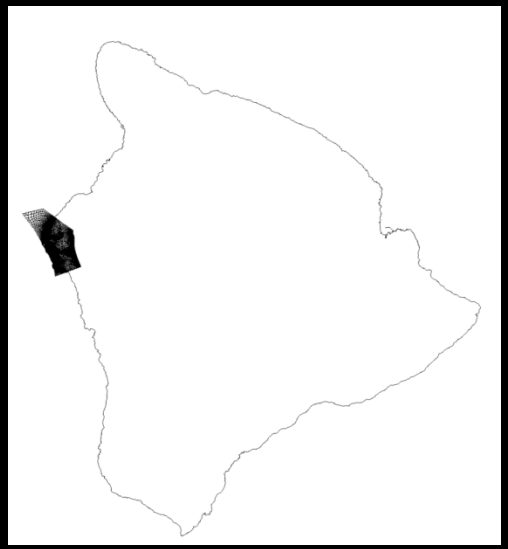
- Chloride concentration increases by 90 mg/L in selected damselfly pools

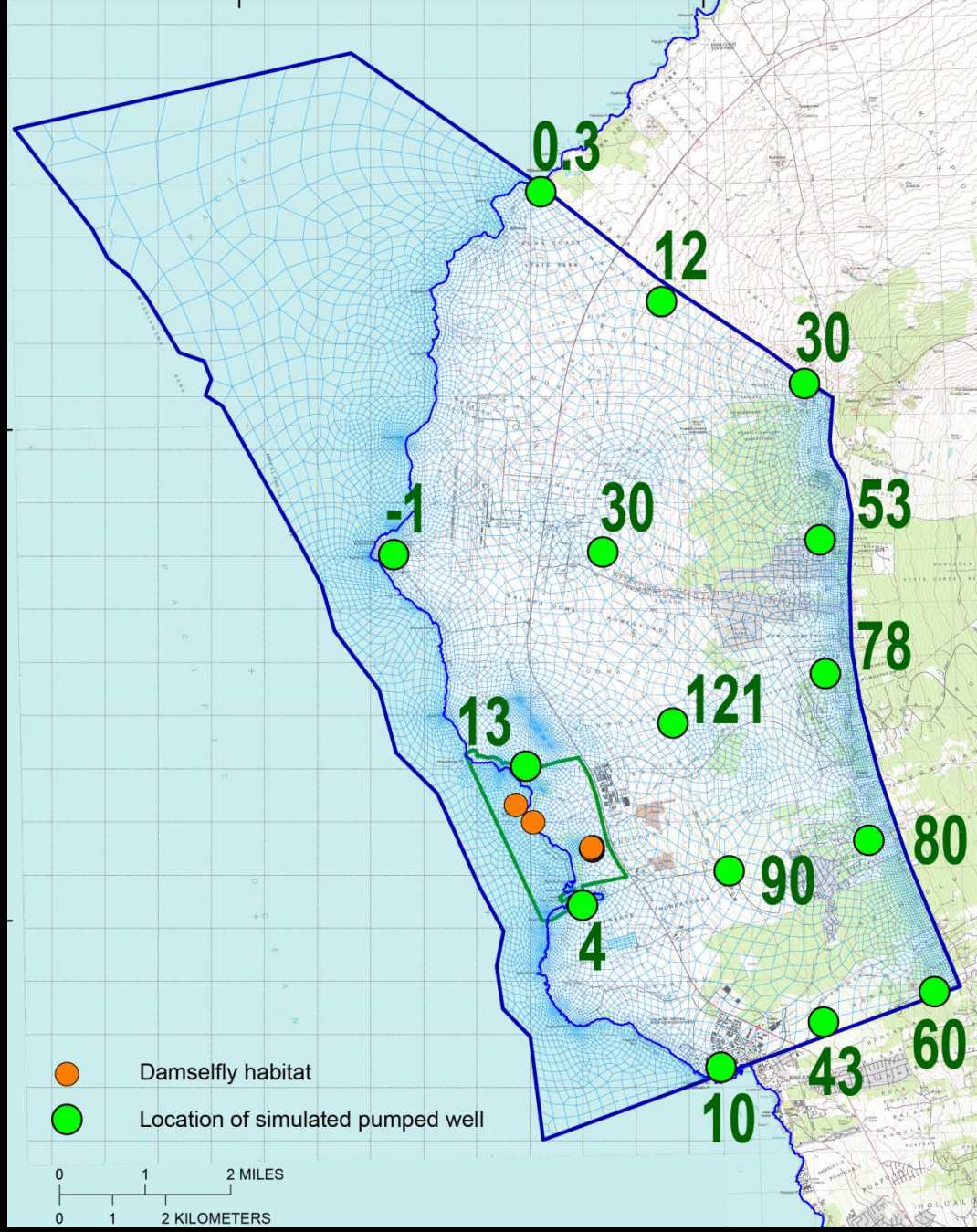




0.5 Mgal/d From Indicated Site (1 to 15)

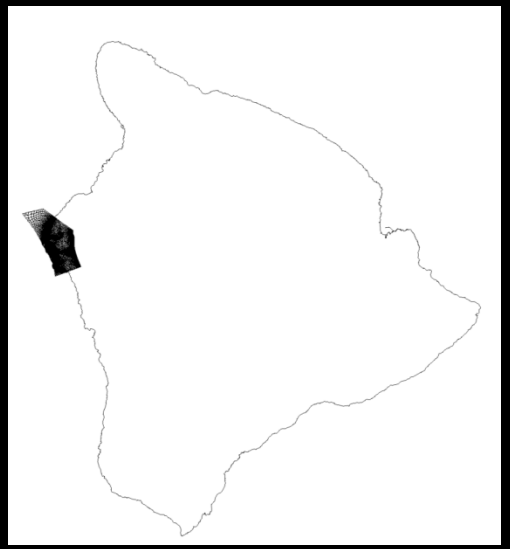
- Pump one site at a time
- Posted values indicate chloride-concentration increase (mg/L) in selected damselfly pools caused by pumping 0.5 Mgal/d at an indicated site

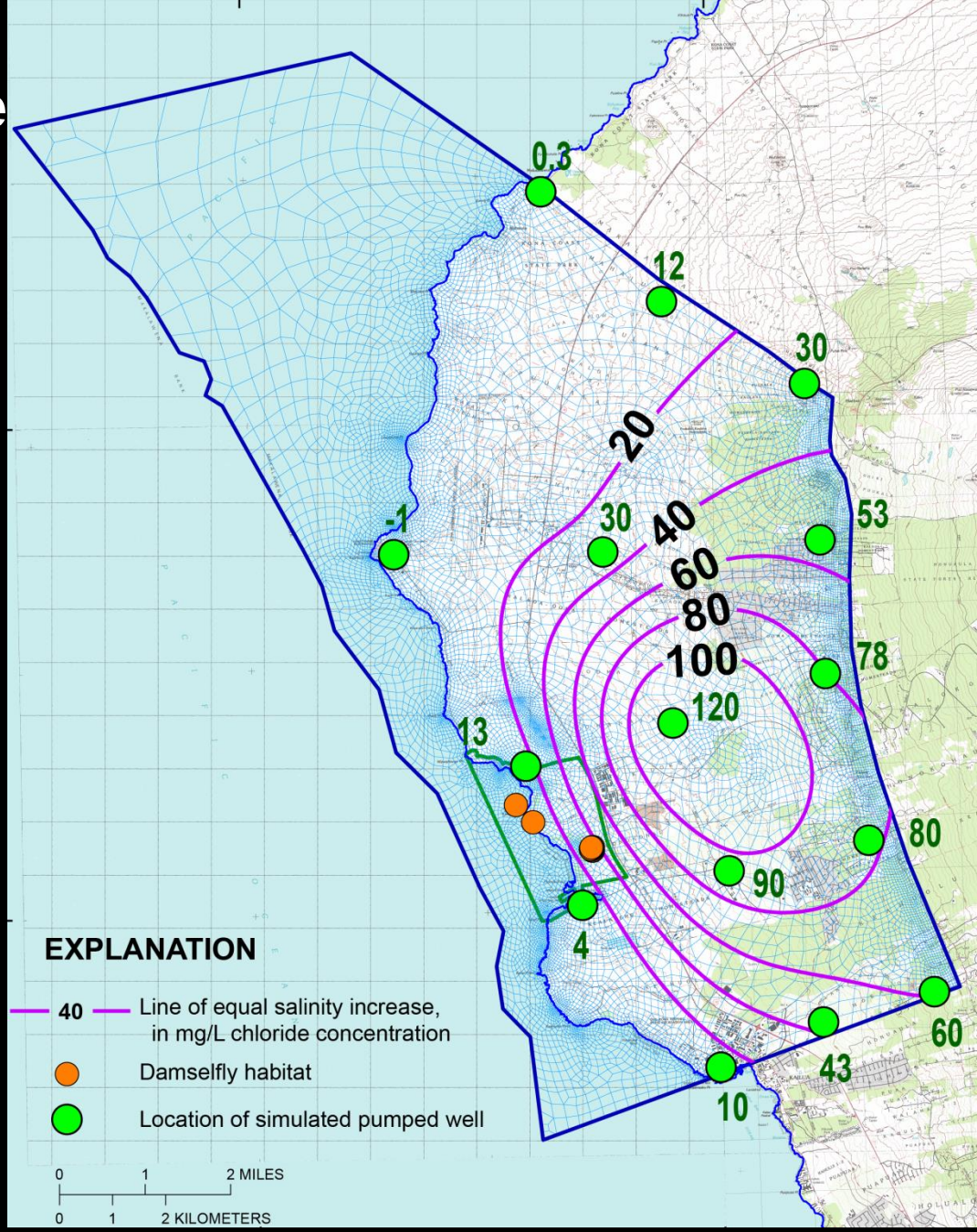




Simulated Salinity Increase

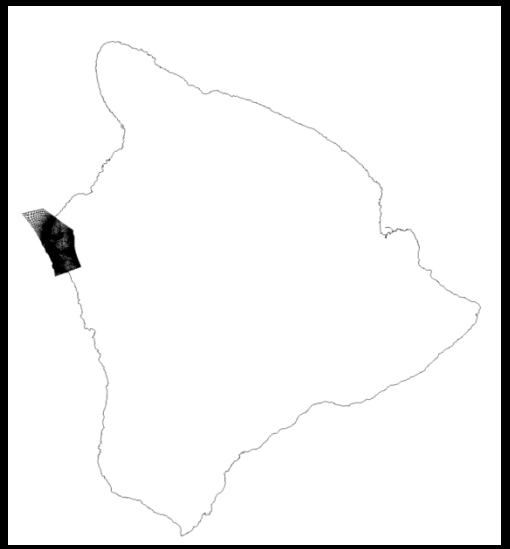
- Contours indicate chloride-concentration increase (mg/L) in selected pools caused by pumping 0.5 Mgal/d from a site along the contour

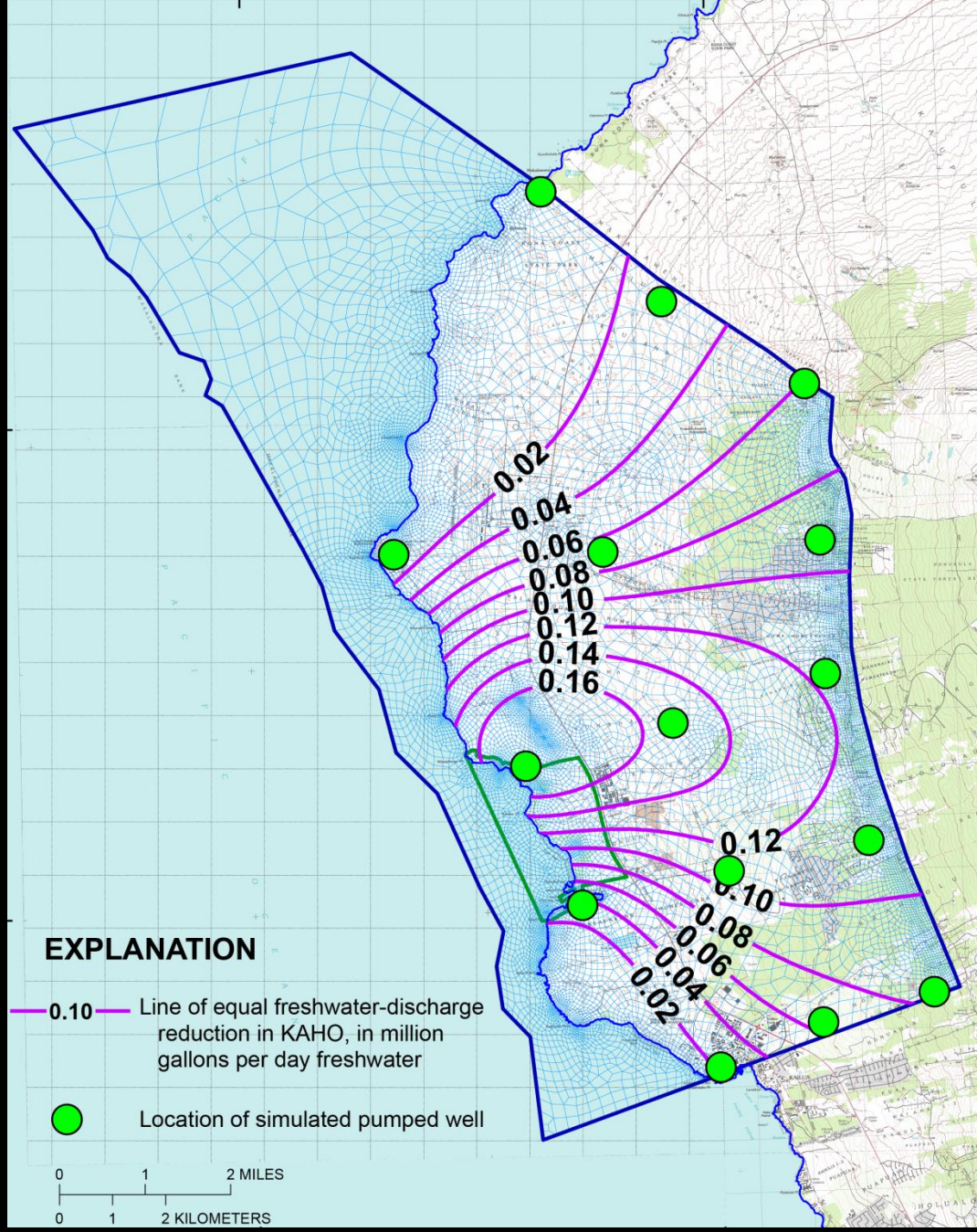




Simulated Discharge Reduction Through Park

- Contours indicate freshwater-discharge reduction in the Park caused by pumping 0.5 Mgal/d from a site along the contour





Overall Summary

- Recent information from wells in Keauhou indicates:
  - a deep zone of freshwater exists beneath the coastal freshwater-lens system
  - an unusually thick transition zone in northern Keauhou
- Geochemistry data indicate groundwater in the coastal freshwater-lens system consists of a mixture of water types, including a component of high-level groundwater
- Numerical groundwater modeling improves conceptual understanding of the groundwater-flow system and provides estimates of effects of withdrawals
- Existing information and modeling are consistent with some degree of hydrologic connection between the high-level and coastal groundwater systems

Data Needs

- Additional deep wells needed to improve understanding of:
  - the hydrogeological setting of Keauhou
  - the effects of withdrawals from the high-level groundwater system on coastal resources

- Geophysical methods can potentially provide geologic, hydrologic, and geometric insights on the high-level and deep groundwater systems but these methods rely on wells for ground-truth data

- Geochemistry can potentially be used to provide insights on the recharge area of the Keauhou aquifer system


Questions
Keauhou groundwater exposed
in a surface depression
USGS